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Level 1 Environmental Assessment of Electric Submerge-ARC Furnaces Producing Ferroalloys

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The report gives results of an EPA/IERL-RTP Level 1 multimedia environmental assessment of the ferroalloy industry. It contains general industry statistics and results of sampling and analysis at three plants (six furnaces total). It indicates that the potential for serious environmental problems exists in some segments of the industry, but it does not prove that the pollution problems are occurring. Specifically, the pollution potential for covered (mix-sealed and sealed) furnaces is substantially higher than for open furnaces, primarily due to the high concentration of organics in gases generated by the former. Covered furnaces generate polycyclic organic material (POM) at the rate of about 1,230-11,080 kg/yr per MW of furnace capacity (or 208,800-1,878,800 kg/yr for all U.S. covered furnaces). Open furnaces generate POM at about 100-900 kg/yr per MW furnace capacity (or 134,500-1,210,500 kg/yr for all U.S. open furnaces). No growth is expected in the use of covered furnaces, comprising only 14% of the industry's production capacity. The estimated nationwide POM generation rates (before emission control devices) are in the same order of magnitude as those of slot-type coke ovens, which EPA considers to be major emitters; however, the control devices used on all U.S. ferroalloy furnaces remove most of this material from the gas stream.

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LEVEL 1 ENVIRONMENTAL ASSESSMENT OF ELECTRIC SUBMERGED-ARC FURNACES PRODUCING FERROALLOYS

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ABSTRACT

An EPA-IERL/RTP Level 1 multimedia environmental assessment of the ferroalloy industry was conducted. The report contains general industry statistics and the results of sampling and analysis at three plants (six furnaces total).

The industry is facing severe pressure from imported products and its continued viability is uncertain. In addition, this report indicates that the potential for serious environmental problems exists within some segments of the industry but does not prove that the pollution problems are occurring. Specifically, the pollution potential of covered (mix-sealed and sealed) furnaces is substantially higher than for open type furnaces, primarily due to the high concentration of organics in gases generated by covered furnaces. The covered furnaces are estimated to generate polycyclic organic material (POM) at the rate of about 1,230 to 11,080 kg/yr (2,710 to 24,430 lb/yr) per megawatt of furnace capacity or 208,800 to 1,878,800 kg/yr (460,300 to 4,120,000 lb/yr) for all U.S. furnaces of this type. Open furnace POM generation rate is estimated to be 100 to 900 kg/yr (220 to 1,980 lb/yr) per megawatt of furnace capacity or 134,500 to 1,210,500 kg/yr (296,500 to 2,668,700 lb/yr) for all U.S. furnaces of this type. Covered furnaces comprise only 14 percent of the industry's production capacity and no growth in their use is expected. These estimated nationwide POM generation rates (estimated rates before the emission control devices) are in the same order of magnitude as estimated POM generation rates (before control devices) of slot type coke ovens, which EPA considers to be a major emitter. However, the control devices, which are in use on all U.S. ferroalloy furnaces, remove most of this material from the gas stream. Samples from one mix-sealed furnace were analyzed by GC/MS which gave positive identification of known organic carcinogens in

both the clean gas discharged by the scrubber (but before passing through the flare which is expected to destroy some organics) and in the water discharged by the scrubber (which is treated before discharge from the plant). Low resolution mass spectrographic (LRMS) analysis indicates the presence of carcinogens in the cleaned scrubber discharged gas (before flaring) of four of the five scrubber equipped furnaces tested, and the water discharged from all scrubbers tested (before wastewater treatment), and in the gases generated by one open furnace served by a baghouse (emissions from the baghouse were not determined). LRMS indicated the presence of carcinogens in the wastewater discharged by only one (no longer operating) of the three plants tested.

The report indicates areas in which further study and/or emissions quantification is needed.

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*Now at Montana College of Mineral Science and Technology.

1.0 INTRODUCTION

In May 1974, EPA published the results of a study[1] of the ferroalloy industry which would serve as a useful background to this report. The study discusses production methods, atmospheric emissions, pollution control equipment, and the cost of air pollution control. In October of 1974, EPA published two volumes[2] containing background information for standards of performance which gave justification for guidelines on particulate emissions. Background information documents have also been published for water pollution from submerged arc furnaces,[3] from electrolytic ferroalloys,[4] and for calcium carbide manufacture.[5] All of these sources provide information useful to the reader.

While developing the guidelines for particulate emissions, EPA gave serious consideration to standards that would require the use of sealed type ferroalloy furnaces. The test data showed, among other advantages, that particulate emissions from sealed furnaces were significantly lower than from open type ferroalloy furnaces. Industry objected to adoption of this alternative on the grounds that sealed furnaces seriously restricted their ability to manufacture different families of ferroalloy products in the same furnace and could reduce their ability to respond to rapidly changing market demands. EPA agreed with this objection and based the standards on best available control technology for open type furnaces.

EPA did, however, decide to further investigate the subject of product flexibility recognizing that solution of this problem could ultimately lead to standards of performance based on sealed furnace technology. This task was assigned to EPA's Industrial Environmental Research Laboratory (IERL) in Research Triangle Park, N. C. As a first step, IERL analyzed some of the samples previously obtained and found indications that sealed furnaces generated substantially more organics, including polynuclear aromatics (PNA), than did open furnaces, however, open furnaces also generated significant quantities of these materials. To verify this finding, gases generated by one sealed furnace, which was alternatively producing silicomanganese and ferromanganese, were sampled and analyzed.[6] That study, which experienced some sampling difficulties, did indicate that a significant concentration of PNAs exist in the gases generated by the furnace and that high energy venturi scrubbers might be effective in their capture.

Since there are closed, mix-sealed, and open furnaces in this country prudence dictated that pollutants generated by and discharged from ferroalloys furnaces be more fully characterized. The present study is the first phase of this effort. A complete multimedia environmental assessment of the industry was desired, however, funding limitations prevented such a comprehensive study. The study design which resulted from consideration of funding limitations, and the need to explore the pollutant generation potential of several ferroalloy furnaces, particularly the mix-sealed type, does not include furnace types and mode of pollution control (i.e., baghouse or scrubber) in the same proportions as they exist in the industry. The design is believed, however, to accomplish the next logical step in the assessment and to represent the best approach for the available funds.

The primary objective of this study is to determine if there is a significant difference in the types and amounts of organic pollutants generated by open and mix-sealed furnaces. To accomplish this objective, detailed testing, by EPA-IERL/RTP Level 1[7] procedures, was done at three plants, two furnaces at each plant. Both open and mix-sealed furnaces were tested and products included ferromanganese, 50 percent ferrosilicon, and 75 percent ferrosilicon. The study design does not allow a complete elucidation of the separate effects of furnace type and product manufactured. Also, since the gas from mix-sealed furnaces is flared, the actual organic emission to the atmosphere generally cannot be determined.

This report is intended for use by EPA and industry in assessing the pollution potential of submerged arc furnace production of ferroalloys and as a guide in prioritizing their future expenditures of research funds and efforts.

2.0 SUMMARY OF STUDY

2.1 FERROALLOY PRODUCTION

The United States is one of the world's largest producers and consumers of ferroalloys. Annual ferroalloy production in the U.S. is about 1.45 million tonnes (1.6 million tons). Consumption of ferroalloys by the U.S. is about 2.1 million tonnes (2.3 million tons) annually. Domestic production has decreased steadily since 1972 and is now at about 1945 levels. Imports have risen from 2.4 percent of domestic consumption in 1945 to over 45 percent in the years since 1975. This situation has arisen, not because of a reluctance to produce by the domestic industry, but because imported materials are cheaper. The availability of imports at lower prices is due to many factors including lack of environmental restrictions, cheap energy, and, the industry claims, dumping of ferroalloys on the U.S. market at unfair prices. The industry has repeatedly said that unless the U.S. government takes positive action to limit the influx of imports, possibly through quotas and high tariffs, the American ferroalloy industry will not survive.

2.2 MANUFACTURING METHODS

Ferroalloys are manufactured primarily in submerged arc electric furnaces. Other production and refining methods are vacuum and induction furnaces, exothermic (alumino-silico-thermic) processes and electrolytic manufacture of high purity metals.

The submerged arc furnace consists of a refractory lined crucible with a tap hole near the hearth level to withdraw the molten product. Power is supplied to the furnace through carbon electrodes which extend downward through the charge material to a point slightly above the hearth. Charge materials, which include ores, scrap iron, gravel, coal, coke, and sometimes woodchips, are fed to the furnace as required to keep the crucible filled. The electric current passing into the furnace raises the temperature of the charge into the range that the reduction reactions (basically removal of oxygen from the metals) can occur. Large volumes of carbon monoxide gas are produced in the reduction reactions. Furnace power consumption rates ranges from about 7 megawatts to over 50 megawatts depending on furnace size and product being made.

2.3 SUBMERGED ARC FURNACES

Furnaces are categorized by the type of furnace top cover used. There are two basic categories (open and covered) and two subtypes for each basic category. The open category is considered herein to be composed of totally open furnaces in which there is an open gap of one meter or more between the crucible top and the fume collecting hood, and close hooded in which this gap is significantly reduced by movable doors or panels that reduce the amount of air drawn into the hood system. The covered category includes the mix-sealed furnaces in which a tight-fitting cover is installed on the crucible and is partially sealed by raw materials mounded over the openings in the cover through which the electrodes pass, and sealed furnaces which are similar to the mix-sealed furnace except mechanical seals are used around the electrodes. Two emission control systems are used with covered furnaces, one system to withdraw gases from beneath the cover (primary control system) and a hood system above the cover to collect fumes escaping the cover (secondary control system).

There are advantages and disadvantages for each type of furnace. The covered furnaces are advantageous because the gas volumes requiring collection and treatment are considerably less (sometimes by as much as a factor of 50) than for open furnaces. The disadvantages are that a scrubber must be used in the primary emission control system of the furnace because the gas contains high concentrations (20-90 percent) of combustible gases (explosion hazard) and organic tar (the cleaned gases are either flared or used for fuel value) and that only certain types of products can be manufactured. Stoking the furnace charge is not possible with the covered furnaces, and some products tend to form bridges in the furnace which can lead to violent ejection of gas, charge material, and occasionally molten metal, when the bridge collapses.

Open furnaces have the advantages that stoking is possible; thus, almost any product can be manufactured, with appropriate modifications to electrode spacing, and that only one system is required for collection of gases generated by the furnace (does not include tapping controls, etc.). Another advantage is that the gas burns as it leaves the surface of the charge material in the furnace, destroying the carbon monoxide and most organics. The major disadvantage is that large volumes of gas must be handled by the collection and capture system.

2.4 GENERAL POLLUTION POTENTIAL FROM SUBMERGED ARC FURNACES

The pollution potential of covered furnaces is primarily due to high concentrations of organics in the gases generated by the furnaces. Data presented later show that the capture efficiency of scrubbers is greater for particulate matter than for organics. The particulate escaping the scrubbers contains 1-4 percent organic matter, generally high molecular weight compounds, and includes polycyclic organics and known carcinogens. Flares are used to burn the gases exiting the scrubbers. They are normally (but not always) operating. The effectiveness with which the flares destroy the organic material has not been determined. Scrubber discharge waters also contain the organics and may present problems with solid waste disposal and discharged water. Fumes going to the secondary and tapping emission system may also contain organics.

Baghouses, which are generally recognized to be effective in removal of particulate from gas streams, are used on most open furnaces. Significant amounts of dust were observed around some baghouses which indicate a transfer problem (scattering of the dust by winds is possible) at some plants. Calculations presented later indicate that baghouses have a low potential for capturing organics, including fused aromatics and possibly carcinogens, generated by the open furnaces. Scrubbers are used on some open furnaces, and although generally effective for particulate control, are less effective for organic capture. The use of scrubbers introduces the possibility of metals and organics in plant discharge water and leaching or percolation of these components from the wastewater ponds. Energy usage by scrubbers is higher than for baghouses.

Fumes are generated during tapping and are difficult to capture. These fumes may contain organics which probably come from material used to plug the tap hole and line the tap lip.

2.5 SOLID WASTE DISPOSAL

About 363,000 tonnes (400,000 tons) of solid waste are generated annually by the ferroalloy industry or about 9,100 tonnes (10,000 tons), on the average, for each plant. About 30 percent of this material may contain wastes specifically listed as hazardous by proposed section 3001 of the Resources Conservation and Recovery Act (RCRA). About 85 percent of the waste is disposed of in landfills or lagoons which are unlined. The dusts and sludges may contain about 0.1 or 8 percent organic matter for open and covered furnace production, respectively. Sludges, from covered furnaces in particular, may contain high concentrations of polynuclear aromatic hydrocarbons including known carcinogens. Industry tests indicate that the dusts form a hard, fairly impermeable mass (permeability K values of 10^{-4} to 10^{-8} cm/sec) when wetted and allowed to dry. Industry data from monitor wells show virtually no contamination of groundwater based on analysis for five metals (Ba, Cd, Cr, Pb, and Hg). No data are available on organic leaching from these sludges. To the best of our knowledge, there is no evidence available to prove or disprove that sealing occurs.

2.6 FORMATION AND DEGRADATION OF POLYCYCLIC ORGANIC MATTER

Extrapolations of the data indicate that polycyclic organic matter (POM) are generated by covered furnaces at the rate of about 1,230 to 11,080 kg/yr (2,710 to 24,430 lb/yr) per megawatt of furnace capacity or 208,800 to 1,878,800 kg/yr (460,300 to 4,120,000 lb/yr) for all U.S. furnaces of this type. POM generation by open furnaces is estimated to be about 100 to 900 kg/yr (220 to 1,980 lb/yr) per megawatt of furnace capacity or 134,500 to 1,210,500 kg/yr (296,500 to 2,068,700 lb/yr) for all U.S. furnaces of this type. Calculations for both furnace types are based on generation rates and are before collection and treatment by emission control equipment. Thus, estimated nationwide POM generation rates by ferroalloy furnaces are in the same order of magnitude as the POM generation rate of slot type coke ovens, a major POM emitter, which are estimated to be 317,000 to 3,200,000 kg/yr (7,000 to 7,000,000 lb/yr) for all U.S. coke ovens.

Some of this POM is captured by baghouses, some is destroyed by flares, some escapes to the atmosphere and some, probably most, is collected in scrubber waters. Information is presented which indicates that the POM concentration in the clarified scrubber water should be less than its solubility in pure water (POM materials are preferentially absorbed on suspended solids). Since suspended solids are generally removed from the scrubber water before chemical wastewater treatment and since previous research has shown that POMs degrade at a slow rate, it is likely that most POMs collected by the scrubber accumulate in solid waste disposal sites and disposal lagoons.

Research work on the fate of polynuclear aromatic hydrocarbons (PNA), a subcategory of POM, in the atmosphere has shown that nonmutagenic PNA can be converted to active mutagens in air containing as little as 1 ppm (volume) of NO_2, a typical urban pollutant.

2.7 ENERGY REQUIREMENTS

The industry consumes about 8,900,000 megawatt hours of electricity annually. Pollution control devices account for about 6 percent of this total. About 2 percent of the power used in operating sealed furnaces is for pollution control and up to 11 percent of the power used in operating open furnaces is for pollution control. Surprisingly, pollution control energy requirements for mix-sealed furnaces with both primary and secondary emission control system are almost the same as for open furnaces.

2.8 SAMPLING TEST RESULTS

Two furnaces at each of three plants were tested. Scrubbers were used on five of the furnaces and samples were taken of scrubber waters and of the scrubbed gas before it was flared. The one furnace tested which was served by a baghouse was sampled before the pollution control devices. Samples were also taken of the plant discharge wastewaters. All sampling was done by IERL/RTP Level 1 procedures which should yield results accurate to within at least a factor of three of the actual concentration in the stream sampled. Analysis of the samples concentrated on the organic material and only limited testing was done for inorganic components.

The furnaces tested, products being manufactured, operating power level, and type of pollution control equipment are presented in Table 1.

TABLE 1. FERROALLOY FURNACES TESTED

Furnace	Type	Product	Power MW	Primary Emission** Control System
A-1	Mix-sealed*	FeMn	11.4	Scrubber - High Energy
A-2	Open	FeMn	15.8	Scrubber - *** Medium Energy
B-1	Open	50% FeSi	48.4	Baghouses
B-2	Mix-sealed	50% FeSi	48.0	Scrubber - High Energy
C-1	Mix-sealed	75% FeSi	15.5	Scrubber - Low Energy - Disintegrator type
C-2	Mix-sealed	50% FeSi	16.8	Scrubber - Low Energy - Disintegrator type

*Mix-sealed furnaces vary in the degree of undercover combustion. Essentially complete combustion was occurring in furnace A-1 during tests. Substantially less combustion was occurring in the other mix-sealed furnaces tested.

**Flares are used to burn the scrubbed gas on all mix-sealed furnaces.

***Designed for high energy but operating at medium energy during test.

Summarized in Table 2 are the particulate generation rates by the furnaces (before emission control). The data are only for particulate going to the primary emission control systems. Thus, tapping and product handling are not included. Also not included in the data are particulates going to the secondary emission control systems of mix-sealed furnaces. This should be considered when comparing data for open and mix-sealed

TABLE 2. SUMMARY OF FURNACE PARTICULATE GENERATION DATA

Furnace	Type	Product	Operating Power, MW	kg/hr	kg/MW-hr	kg/Mg alloy
A-1	Mix-sealed	FeMn	11.4	47.3	4.1	10.1
A-2	Open	FeMn	15.8	174.9	11.1	26.0
B-1	Open	50% FeSi	48.4	470.6	9.7	49.2
B-2	Mix-sealed	50% FeSi	48.0	447.7	9.3	46.0
C-1	Mix-sealed	75% FeSi	15.5	196.7	12.7	103.0
C-2	Mix-sealed	50% FeSi	16.8	187.9	11.2	68.9

furnaces. For covered furnaces the data are the sum of the particulates captured by and escaping the scrubber. For furnace B-1 the data are for particulates in the gas going to the baghouse.

With the exception of furnace A-1, there does not seem to be a significant difference in particulate generation rates from variations in product type or type of furnace used when compared on a kg/MW-hr basis. Furnace A-1 seemed to be generating more secondary fume (based on visual estimates) than typical mix-sealed furnaces which may account for the low value obtained. When compared on a kg/Mg of alloy produced basis, it appears that particulate generation rates increase in the order of FeMn, 50 percent FeSi, and 75 percent FeSi. The data are not conclusive for different types of furnaces since particulate generation rates of furnaces B-1 and B-2 are comparable but less than for furnace C-2, all 50 percent FeSi product. The difference may be due to lower efficiency (kw-hr/kg product) in furnace C-2.

Summarized in Table 3 are the organic generation rate data (equivalent to Table 2 for particulates). In this case, significant differences are noted when the generation rates are compared on either a kg/MW-hr and kg/Mg basis. The open furnaces obviously have lower overall organic generation rates than the mix-sealed furnaces in which limited combustion was occurring. It is interesting to note the variation in organic generation rates by the different mix-sealed furnaces. Although the same product was being made in furnaces B-2 and C-2, the organic generation rates differ by almost a factor of 3. (A wider variation than expected for determination of total organics by Level 1 procedures.) This is probably due to more combustion under the cover of furnace C-2 (reflected in the Orsat analysis in Section 12). This would lead one to believe that the organics generated in furnace C-1 could be substantially higher if less undercover combustion was occurring. Most interesting are the results for furnace A-1 which had almost complete undercover combustion. The trend observed for the mix-sealed and open furnaces strongly indicates that more complete destruction of organics would occur in sealed or mix-sealed furnaces in which complete undercover combustion was occurring.

TABLE 3. SUMMARY OF FURNACE ORGANIC GENERATION DATA

Furnace	Type	Product	Operating Power, MW	kg/hr	kg/MW-hr	kg/Mg alloy
A-1	Mix-sealed	FeMn	11.4	0.72	0.06	0.15
A-2	Open	FeMn	15.8	5.5	0.35	0.82
B-1	Open	50% FeSi	48.4	12.0	0.25	1.25
B-2	Mix-sealed	50% FeSi	48.0	76.7	1.60	7.89
C-1	Mix-sealed	75% FeSi	15.5	19.6	1.27	10.27
C-2	Mix-sealed	50% FeSi	16.8	9.9	0.59	3.65

Given in Tables 4 and 5 are, respectively, the data for particulate and organic in the cleaned gas discharged from the scrubbers but before passing through the flares, if used. Thus, particularly for organics, the value may be higher than actually emitted to the atmosphere since some destruction of organics by the flare is expected. With the exception of furnaces B-1 (which was sampled before emission control equipment), A-1 and B-2, particulate emission levels are near or exceed the New Source Performance Standards (NSPS). (Do not apply to these furnaces). Inclusion of secondary and tapping fumes could have resulted in most furnaces exceeding NSPS requirements.

The efficiencies of the scrubbers for removal of particulate and organic matter from the gases generated by the furnaces are given in Table 6. Although all scrubbers have particulate capture efficiencies of over 90 percent, a significant difference in capture efficiency for organics is observed. As espected, the capture efficiency increased with an increase in either pollutant inlet concentration or scrubber pressure drop.

The concentrations of particulate and organic in the plant discharge wastewaters is given in Table 7. These effluents do not contain cooling or sanitary water.

All samples collected during the test were extracted with methylene chloride and analyzed by infrared (IR) and low resolution mass spectrograph (LRMS). The analyses are not adequate for individual compound identification but do indicate compound categories and potential compounds present. Both the cleaned gas and the water discharged by the scrubber used for control of fumes generated by furnace C-2 were analyzed by gas chromatograph-mass spectrograph (GC-MS) for exact compound identification.

The IR and LRMS analysis of furnaces A-1, A-2, and B-1, all of which were achieving nearly complete combustion of the furnace gas, indicate a low concentration of most organic categories. Potentially low concentrations of the carcinogens, indeno(1,2,3-cd)pyrene and dibenzochrysene isomer, in emissions to the air from furnace A-2 are indicated by LRMS responses at masses 276 and 302, respectively. Similarly, low concentrations of the carcinogens, benzanthracene and benzo(a)pyrene, in gases

TABLE 4. SUMMARY OF PARTICULATE AIR EMISSION DATA*

Furnace	Type	Product	Operating Power, MW	Concentration mg/nm^3	kg emitted per hour	kg emitted per MW-hour	kg emitted per Mg alloy
A-1	Mix-sealed	FeMn	11.4	49.9	0.76	0.07	0.16
A-2	Open	FeMn	15.8	27.7	5.32	0.34	0.79
B-2**	Mix-sealed	50% FeSi	48.0	248.8	2.24	0.05	0.23
C-1	Mix-sealed	75% FeSi	15.5	825.1	7.75	0.50	4.06
C-2	Mix-sealed	50% FeSi	16.8	1242	12.96	0.77	4.75

*Calculated assuming the flares on furnaces B-2, C-1, and C-2 do not affect particulate emission rates. Test data indicate that up to 4 percent of the particulate from mix-sealed furnaces may be organic matter that may be destroyed by the flare.

**Only 1/4 of stated value actually goes to the flare and discharge to the air; 3/4 of the gas goes to the lime kiln.

TABLE 5. SUMMARY OF DATA FOR ORGANICS IN SCRUBBER DISCHARGE GAS*

Furnace	Type	Product	Operating Power, MW	Concentration mg/nm^3	kg emitted** per hour	kg emitted** per MW-hour	kg emitted** per Mg alloy
A-1	Mix-sealed	FeMn	11.4	20.03	0.31	0.027	0.07
A-2	Open	FeMn	15.8	23.98	5.6	0.29	0.68
B-2	Mix-sealed	50% FeSi	48.0	283.72	2.55	0.05	0.26
C-1	Mix-sealed	75% FeSi	15.5	487.43	4.58	0.30	2.40
C-2	Mix-sealed	50% FeSi	16.8	195.6	2.04	0.12	0.75

*This table summarizes the organic data obtained by sampling in the duct immediately after the scrubber and before the flare, if used. It is expected that the flare will destroy a substantial fraction of the organics, but adequate test methods do not yet exist to prove this. For furnace B-2, 3/4 of the gas is burned in a lime kiln with only 1/4 of the stated value going to the flare. For furnaces A-1 and A-2 the data are for emissions to the atmosphere since the flare of furnace A-1 could not operate (the gas burned under the furnace cover) and a flare is not used on furnace A-2. The flares on furnaces C-1 and C-2 were operating about 75 percent of the time during the test.

**As used here, the term 'emitted' means material in the cleaned gas leaving the scrubber. Refer to the note above.

TABLE 6. SCRUBBER EFFICIENCIES, PERCENT

Furnace	Efficiency for particulates	Efficiency for organics
A-1	98.4	57.2
A-2	97.0	16.2
B-2	99.5	96.7
C-1	96.1	76.7
C-2	93.1	79.5

TABLE 7. PLANT WASTEWATER DISCHARGE

	Suspended Solids		Organics	
Plant	mg/l	kg/day	mg/l	kg/day
A	9.4	230	6.7	163
B	2.3	25	12.0	131
C	17.8	145	8.0	65

generated by furnace B-1 (before emission control equipment) are indicated by LRMS responses at masses 228 and 252, respectively. No evidence of potential carcinogens was found in emissions to the air (primary emission control system) from furnace A-1. The scrubber discharge water from furnace A-1 contained organic compounds with masses (LRMS analysis) of 228, 252, 256, and 302 which could be the carcinogens, benzanthracene, benzo(a)-pyrene, dimethylbenzoanthracene, and dibenzochrysene isomer, respectively. The scrubber discharge water from furnace A-2 contained, in addition to the cited organic for furnace A-1, masses at 266 and 276 (dibenzofluorene and indeno(1,2,3-cd)pyrene, respectively).

The scrubbed gases from the covered furnaces B-2, C-1, and C-2 (measured before the flares) all contain similar types of organic compounds although the concentration from the B-2 furnace is lower than from the other two, presumably due to the higher scrubber efficiency for furnace B-2. For these furnaces, the LRMS analysis indicates significant concentrations of fused aromatic organics at masses 252, 266, 276, and 302 which could be the carcinogens, benzo(a)pyrene, dibenzofluorene, indeno(1,2,3-cd)pyrene, and dibenzochrysene isomer, respectively. All scrubber discharge waters from these furnaces contain relatively high concentrations of organics with masses 228, 252, 256, 266, 276, and 302 which could be the carcinogens cited previously. Evidence for potential carcinogens (at masses 228 and 252) was found only in the treated process discharge water from plants C. No evidence of organic carcinogens was found for the treated water discharged from plants A and B.

The GC-MS analysis of the scrubbed gases from furnace C-2 (before flaring which should destroy some organics) gave positive identification of 13 polycyclic aromatic hydrocarbons (PAH) including the known carcinogens, benz(a)anthracene, chrysene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene. Another 10 PAHs were tentatively identified and include the known carcinogen, benz(j)fluoranthene. Comparison of these data and the Level 1 organic data with DMEGs data indicate that benzo(a)pyrene in the scrubbed but not flared gases from furnace C-2 exceed the DMEG value by up to a factor of 80,000. Likewise, benzo(a)anthracene could exceed the DMEG value by a factor of up to 230.

To summarize these data, it seems clear that all ferroalloy furnaces produce compounds that could be carcinogenic and that open types (where the furnace gas is burned before reaching the emission control equipment) produce substantially less than the covered (mix-sealed type) furnaces in which little or no combustion occurs. Scrubbers used on the mix-sealed furnaces capture a large fraction of the organic matter generated.

3.0 CONCLUSIONS

The conclusions of this report are based, in part, on sampling and analysis data obtained using EPA-IERL/RTP Level 1 assessment procedures which yield final results accurate to within at least 1/3 to 3 times the actual value of the stream sampled. This approach is used to identify potential environmental problems and is not in itself sufficient proof that a problem exists. Appropriately, therefore, the data are interpreted using the worst case approximation unless data exist to prove this approximation invalid. Readers should be particularly cognizant of this when reviewing LRMS and organic compound interpretations. While to some, the conclusions may seem to be more positive than permissible considering the accuracy of the data, they are consistent with the Level 1 philosophy briefly outlined above.

1. U.S. production of ferroalloys has declined during the last decade to about 1945 levels. Imports have risen from about 2.4 percent of domestic consumption in 1945 to over 40 percent in the years since 1975.
2. Unless action is taken soon to stem the tide of imports, the continued viability of the U.S. industry is questionable.
3. There are no plans to expand U.S. production capacity. Rather, some furnaces are idle, some plants are being closed, and some older furnaces are being replaced by larger, more efficient furnaces.
4. There are basically two types of furnaces; open, 86 percent of installed capacity, in which combustion of the furnace gas occurs before the emission control equipment, and covered, 14 percent of installed capacity, in which the gas is combusted after passing through the emission control system.
5. The pollution potential of covered (mix-sealed) furnaces is substantially higher than for open furnaces, primarily due to much higher organic generation rates by the covered furnaces. However, mix-sealed furnaces appear to vary in the rate of organic production (kg/MW-hr basis) probably due to varying rates of combustion under the furnace cover. Open furnaces are estimated to generate POM at the rate of about 100 to 900 kg/yr (220 to 1,980 lb/yr) per megawatt of furnace capacity or 134,500 to 1,210,500 kg/yr (296,500 to 2,668,700 lb/yr) for all U.S. furnaces of this type. The covered

furnaces are estimated to generate POM at the rate of about 1,230 to 11,080 kg/yr (2,710 to 24,430 lb/yr) per megawatt of furnace capacity or 208,800 to 1,878,800 kg/yr (460,300 to 4,120,000 lb/yr) for all U.S. furnaces of this type. Control devices, which are in use on all U.S. furnaces, remove most of this material from the furnace gas. Thus, the estimated nationwide POM generation rates (estimated rates before the emission control devices) are in the same order of magnitude as POM generation rates (before control devices) of slot type coke ovens, a major POM emitter, which are estimated to be 317,000 to 3,200,000 kg/yr (700,000 to 7,000,000 lb/yr) for all U.S. coke ovens.

6. The industry generates about 363,000 tonnes (400,000 tons) of solid waste annually. About 85 percent of which is disposed of in unlined lagoons and landfills. Although the wastes contain known and/or suspected hazardous inorganic and organic materials, there is some evidence that the wastes are self-sealing and that heavy metals do not leach into the groundwater.

7. The industry consumes about 9 million megawatt hours of electricity annually, 6 percent of which is used for pollution control. Open and mix-sealed furnaces use up to 5 times as much energy for pollution control as does a typical totally sealed furnace.

8. For the six furnaces tested, there appears to be no significant difference in the kg of particulate generated/megawatt hour of furnace power (before emission control) as a function of furnace size, type, or product being manufactured. There does appear to be a difference in the kg of particulate (per megawatt hour of furnace power) in the gas discharged from the scrubber, which appears to be related to scrubber design and pressure drop, but may also be a function of furnace type and/or product being manufactured.

9. Scrubbers appear to be less efficient for capturing organics than for particulate capture.

10. Low resolution mass spectrographic analysis indicates the potential presence of carcinogens in the cleaned gas from the scrubbers, before it was flared, from four of five furnaces tested (the exception being one mix-sealed furnace in which complete undercover combustion was apparently occurring), and in the gas from one open furnace which was tested before emission control.

11. Low resolution mass spectrographic analysis indicates the presence of potential carcinogens in all scrubber discharge waters and in the plant discharge water from only one plant (no longer operating) of the three tested.

12. Analysis of samples of one mix-sealed furnace by GC-MS techniques gave positive identification of known carcinogens in the cleaned gas discharged by the scrubber (but before passing through the flare which may destroy some of the organics) and in the scrubber discharge water (before wastewater treatment). Two of these carcinogens could exceed

DMEG values by factors of up to 200 and 80,000, respectively, if significant destruction does not occur in the flare. These data provide strong evidence that the preliminary identifications listed above in 10 and 11 are probably correct.

13. Based on information obtained in these tests, we must conclude that a potential for a significant multimedia environmental problem exists with ferroalloy manufacture and that this potential is significantly greater for plants using mix-sealed and sealed furnaces than for those using open furnaces. It has not been established that a real environmental problem exists in any of the three media--air, water, or solid waste.

4.0 RECOMMENDATIONS FOR FUTURE WORK

Identified in this report are several areas where the IERL/RTP Level 1 approach indicates that a potential exists for significant environmental problems. This section indicates the areas in which the Level 2 and Level 3 work should proceed in order to provide a complete and accurate environmental assessment.

The Level 1 data indicate significant amounts of organics, including some known carcinogens, are produced by most furnaces, with the largest amount (on a kg/megawatt hour of furnace power basis) being produced by the covered (mix-sealed and sealed) types. Although the covered furnaces make up only 14 percent of the industry (on a power consumption basis), the data indicate they produce as much, if not more, POM than does the 86 percent of the industry using open furnaces. Although the present trend is to retire older covered furnaces, and the industry speculates that any future construction would include only open type furnaces, some covered furnaces will remain in operation and future construction of covered furnaces cannot be ruled out completely. Therefore, it is necessary that any future work consider both types of furnaces.

Any future work should proceed in a straightforward and logical manner. That is, as a first step, more accurate testing should be done to quantify the pollutants produced by the furnaces and determine how much is ultimately discharged to the environment through any and all three media. If these tests should prove that unacceptable amounts of pollutants are emitted, or are disposed in an environmentally unsound manner, work should be initiated to determine if the public is being, or is likely to be, endangered. If these studies indicate public endangerment, studies should be undertaken to reduce pollutant releases from the industry.

Specifically, the following additional work is recommended. More accurate sampling (i.e., isokinetic, duct traverse, integrated composite water sampling) and analysis (GC-MS, for example) need to be used to quantify discharges from the plants to all media. For plants using only open furnaces and capturing and disposing of only dry dust (baghouse control system), sampling will be required for emissions from the baghouse and for surface water runoff and groundwater intrusions from the dust disposal site. A few locations control emissions from open furnaces with scrubbers or slurry the dust captured by the baghouse. The number and size of these facilities are probably not large enough to warrant detailed testing. Sampling in the gas stream before the control device (baghouse) and of the collected baghouse dust is also recommended since these tests will allow a measure of control efficiency for the contaminants, a measure of contaminants entering the disposal sites, and an indication of possible emissions in the event of control device failure (bag rupture, etc.).

Quantifying emissions to the air from covered (mix-sealed and sealed) furnaces is extremely difficult since the gas is flared on discharge to the atmosphere. At present, there are no established techniques for measuring emission rates from flares. It is recommended, therefore, that the gas be sampled in the duct after the scrubber and before the flare. This should provide a reasonable estimate of particulate emissions, although some change in mass is to be expected since flaring may change the form of some of the particulate components and is expected to burn-off some of the organics on the particulate matter. Determining the actual organic emission rate is complicated by the fact that the flare will destroy some of the organic matter and the percentage destruction (for total organics or for individual compounds) cannot be accurately measured. As a first approximation, it can be assumed that the flare is 100 percent effective and the emission rate calculated based on the percent of time that the flares are not operating. (Determination of the average percent of time that flares do not operate may require a brief industry survey.) Other assumptions about flare efficiency could be made. If adequate methods are developed, and actual assessment of flare effectiveness should be made.

The wastewater discharged by the plant should be analyzed for priority pollutants including polynuclear aromatics. The possibility of leaching inorganics and organics into the groundwater at disposal sites and lagoons should be examined. This can be done by analyzing leachate from sludge taken from a selected site and by taking samples from monitor wells at the site. In conjunction with this work, studies should be made of the sludges and dust to determine if they act as sealants for the disposal site.

It is recommended that in conjunction with the above tests, the water discharged by the scrubbers on the furnace be tested since this provides information as to the control efficiency of both the scrubber and the wastewater treatment system.

If the above test should prove that unacceptable amounts of pollutants are emitted or are disposed of in an environmentally unsound manner, work should be initiated to determine if the public is, or is likely to be, endangered. To accomplish this, modeling studies for the pollutants of concern should be done to determine the potential impact on the population surrounding a plant. An assessment of the health records of workers, former employees, and, possibly the nearby population may be useful in connection with this study.

If the weight of evidence gathered indicates public endangerment, work should be initiated to reduce pollutants emitted by the industry. While we cannot predict with certainty which pollutants would be involved or which media would have the most impact, we can suggest some areas in which additional work might be fruitful. Included in these suggested efforts below are some already being instituted by the industry.

1. Improved flare design and operability.
2. Improved scrubber efficiency, particularly for organics.
3. Reduced gas volume from open furnaces, possibly by the use of close hooding.
4. Investigate the possibility of controlled undercover combustion in mix-sealed and sealed type furnaces for organic matter destruction. (This would be a radical departure from conventional operation and would require extensive effort).

5. Investigate improved water treatment methods, including clarification and filtration for improved suspended solid removal and an investigation of the applicability of reuse and/or recycle of wastewater since this has the potential for significantly reducing mass emissions of suspended solids (on which polycyclic aromatic hydrocarbons can be absorbed) and dissolved materials.
6. Investigate alternate methods for treatment or disposal of solid wastes generation.

5.0 INDUSTRY BACKGROUND

Ferroalloy production is a small, but vital part of the iron and steel industry. Ferroalloys are mixtures of iron and alloying elements which when added to molten steel give it the unique character and properties needed for different applications. About 18.1 kg (40 lbs) of the alloy are used in the production of 907 kg (one ton) of steel. This 2 percent addition is a major factor in making the difference between the steel used in a paper clip and that used in the girders for a bridge.

There are hundreds of various compositions and grades of ferroalloys, but they can be grouped into three major categories: Manganese and manganese alloys, silicon and silicon alloys, and chromium and chromium alloys. Small amounts of other ferroalloys are produced which contain alloying metals such as vanadium, columbium, molybdenum, and nickel. Although the iron and steel industry is the largest consumer of ferroalloys, other industries use some of the products. For example, silicon metal is used in the aluminum industry as an alloying agent and in the chemical industry for producing silicones.

Ferroalloy producers supply material to the steel industry and do not, themselves, produce the finished steel product. Steel companies have, however, produced some high carbon ferromanganese in blast furnaces. This process is not considered part of the ferroalloy industry. Conditions in the blast furnace are not adequate to produce other types of ferroalloys.

The classification of some materials as ferroalloys is somewhat arbitrary. Calcium carbide, for example, is sometimes considered a ferroalloy because it is frequently produced at ferroalloy plants and in the same type equipment. Its end use, however, is not the same. Ferrophosphorus is an alloying material produced in the same type equipment as the ferroalloys, but it is considered a byproduct of phosphorus manufacturers. This report concerns itself with the conventional production of ferroalloys in the submerged electric arc furnace. Ferrophosphorus, calcium carbide, electrolytic production of relatively pure metals, vacuum furnace production, and the aluminosilico-thermic processes are essentially not considered.

5.1 INDUSTRY STATISTICS

The U.S. production and consumption of ferroalloys is among the highest in the world and probably rivaled only by the Japanese as the world leader. The industry employs about 8,000 people and has a payroll well in excess of 100 million dollars.

Table 8[8] gives the historical production and consumption of ferroalloys in the United States while Tables 9[8] and 10[8] give the U.S. steel and foundry consumption for the three major categories of ferroalloy products. It is particularly interesting to note that U.S. ferroalloy production has decreased in recent years to about 1945 rates, but imports have grown from 2.4 percent in 1945 to over 40 percent of total U.S. consumption. Table 11[8] gives the total industry power consumption for 1970-1977. Average consumption is, therefore, about 5.66 kw-hr/kg (2.57 kw-hr/lb) of alloy.

Tables 12[8] and 13[8] give some historical data on the expenditure for environmental protection. Pollution control costs are averaging slightly less than 4 percent of industry sales. Power consumed for pollution control is about 6 percent of total power consumed by the industry.

The statistics do not paint a picture of a healthy industry. The severe pressure from imports has limited the industry's ability to build new facilities to meet the domestic need. The industry claims[9,10] that foreign producers have been able to ship products into the United States at a price that doesn't even cover production costs and that some products (e.g., 75 percent FeSi) from developing countries can enter the United States duty free. The industry fears that unless they get "a fair shake from the trade policies of this country"[9] they may be forced out of business.

The industry reports few, if any, plans for any new production furnaces in the near future. The replacement of old, small furnaces by large, more efficient types and closing of plants or shutting down some furnaces appears to be the present trend. Airco, Inc., for example, has sold its entire ferroalloy operations division,[11] and Plant C of this report has been shut down.

TABLE 8. GENERAL STATISTICS ON FERROALLOYS[8]
(FERROMANGANESE, FERROCHROME, FERROSILICON, AND RELATED METALS)

Year	Thousand net tons gross weight Imports	Domestic Consumption	Imports as percent cons.	Domestic Production
1945	39.2	1,607.1	2.4	1,665.7
1950	105.2	1,881.9	5.6	1,785.6
1955	81.6	2,132.9	3.8	2,224.6
1960	143.4	1,816.3	7.9	1,971.8
1965	351.4	2,518.5	14.0	2,585.1
1966	669.2	2,601.1	25.7	2,497.9
1967	342.1	2,294.2	14.9	2,526.2
1968	321.1	2,368.3	13.6	2,438.1
1969	433.0	2,477.2	17.5	2,437.1
1970	372.8	2,206.5	16.9	2,364.2
1971	387.8	2,260.8	17.9	2,163.4
1972	586.0	2,474.7	23.7	2,334.7
1973	716.7	3,008.4	23.8	2,306.4
1974	828.2	2,919.6	28.4	2,107.9
1975	859.0	2,097.7	40.9	1,758.7
1976	993.5	2,269.6	43.8	1,741.6
1977 (P)	1,013.2	2,340.7	43.8	1,629.6

P = Partial year results extrapolated to full year.

TABLE 9. STEEL AND FOUNDRY PRODUCTION[8]

Year	Total raw steel (Million tons)	Alloy steel (Thousand tons)	Stainless steel (Thousand tons)	Fdry cstgs. shipped (Million tons) Iron	Fdry cstgs. shipped (Million tons) Steel
1970	131.5	12,824	1,279	14.8	1.7
1971	120.4	12,173	1,263	14.4	1.6
1972	133.2	13,979	1,564	16.3	1.6
1973	150.8	16,163	1,889	18.1	1.9
1974	145.7	16,962	2,150	16.6	2.1
1975	116.6	15,171	1,111	13.2	1.9
1976	128.0	14,308	1,680	15.0	1.8
1977 (P)	125.3	15,341	1,862	16.0	1.7

TABLE 10. FERROALLOY CONSUMPTION[8]

	Mn	Cr (Thousand S.T.)	Si
1970	906.9	214.2	352.0
1971	820.2	198.2	383.0
1972	878.1	239.4	461.1
1973	1,023.8	315.6	562.9
1974	1,033.4	359.9	534.2
1975	825.5	201.3	393.1
1976	838.0	248.2	453.7
1977 (P)	809.5	257.0	467.5

TABLE 11. POWER CONSUMPTION[8]

	Kilowatt hours
1970	10,306,658,159
1971	9,630,993,011
1972	9,599,319,438
1973	10,299,993,808
1974	10,540,057,686
1975	8,224,474,156
1976	8,935,966,337
1977	8,923,241,136

TABLE 12. ENVIRONMENTAL CONTROL COSTS AND INVESTMENT[8]

	Capital expenditures (millions of dollars		
	All expenditures	Air pollution	Water pollution
1970-1974	181	74	2
1975	109	46	1
1976	65	28	2
1977	41	13	11

TABLE 13. POLLUTION CONTROL COSTS[8]

	Millions of dollars		Millions of kwhrs	
	Pollution control	Industry sales	Pollution control	Industry total
1975	25	680	400	8,224
1976	27	772	512	8,935
1977	33	780	548	8,923

5.2 FERROALLOY PLANTS IN THE UNITED STATES

Table 14[12] gives the current information on ferroalloy plants in the United States. The list is essentially restricted to plants producing the primary products associated with ferroalloy. Thus, the list does not include the plants producing specialty products (i.e., FeMo, NiCb, etc.); plants where only CaC_2 is produced; or production by the electrolytic, vacuum, and alumino-thermic processes. Under current conditions with plants being sold and furnaces being retired, we cannot be certain the listing is completely accurate. Figure 1 shows the locations of plants listed.

TABLE 14. SUBMERGED ARC FERROALLOY FURNACES IN THE U.S., MAY 1980

Producer	Location	Furnace Types	Number Furnaces	Total Capacity by Type, MW	Normal Products	Control Equipment
Alabama Alloys	Woodward, AL	Open	1	7	FeSi	Baghouse
Chromasco Ltd.	Woodstock, TN	Open	4	42	FeCr, FeSi	Aeronetics Scrubber
Compania Minera Autlan, S.A. de C.V.	Mobile, AL	Sealed	1	27	SiMn	Scrubber
Foote Mineral Co.	Graham, WV	Open	3	79	FeSi & Proprietary Alloys	Baghouse
	Keokuk, IA	Sealed	2	35	Silvery iron	Scrubber
Hanna Mining Co.	Riddle, OR	Open	1	12	FeSi	Baghouse
	Wenatchee, WA	Open	4 (one always in standby)	36 (9 MW in in standby)	FeSi, Si Metal	Baghouse
Interlake Inc	Beverly, OH	Open	5	70	Si, FeCrSi, FeCr	Baghouse
	Selma, AL	Open	2	33	Si Metal	Baghouse
International Minerals and Chemicals - TAC Alloys	Bridgeport, AL	Open	1	40	FeSi	Baghouse
	Kimball, TN	Open	1	20	FeSi	Baghouse
Kawecki-Berylco KBI, Cabot	Springfield, OR	Open	1	18	Si et al.	Baghouse
MacAlloy Corp.	Charleston, SC	Open	2	80	FeCr	ESP
Northwest Alloys	Addy, WA	Open	2	45	FeSi, Si	Baghouse

TABLE 14. (Continued)

Producer	Location	Furnace Types	Number Furnaces	Total Capacity by Type, MW	Normal Products	Control Equipment
Ohio Ferroalloys	Philo, OH	Open	7	148/156	FeSi, FeMn, SiMn	Scrubbers and baghouses
	Powhatan, OH	Open	4	54	Si Metal	Baghouse
	Montgomery, AL	Open	3	54	Si Metal	Baghouse
Reynolds Metals	Sheffield, AL	Open	2	28	Si Metal	Baghouse
Stralloy Inc.	Steubenville, OH	Open	4	40	FeCr, FeCrSi	Baghouse
SKW Alloys Inc.	Calvert City, KY	Open	6	139	FeSi, FeMn, SiMn, CrSi	Baghouse
	Niagara Falls, NY	Open	2	45	FeSi, FeCrSi	Baghouse
South African Manganese Amcor Ltd. (SAMANCOR)	Rockwood, TN	Open	7	67/87	FeSi, FeMn, SiMn	Baghouse
Union Carbide Corp.	Alloy, WV	Open	10	182	Si, FeSi, SiMn, FeMnSi, CaSi	Baghouse-Scrubber on one furnace
	Ashtabula, OH	Open Mix-sealed	1 3	50 77	FeSi FeSi	Baghouse Scrubbers
	Marietta, OH	Open Mix-sealed	2 6	45 61/69	FeMn, SiMn FeMn, FeCr	Scrubber Scrubber
	Portland, OR	Open Mix-sealed	1 2	8 12	SiMn FeMn	Baghouse Scrubber

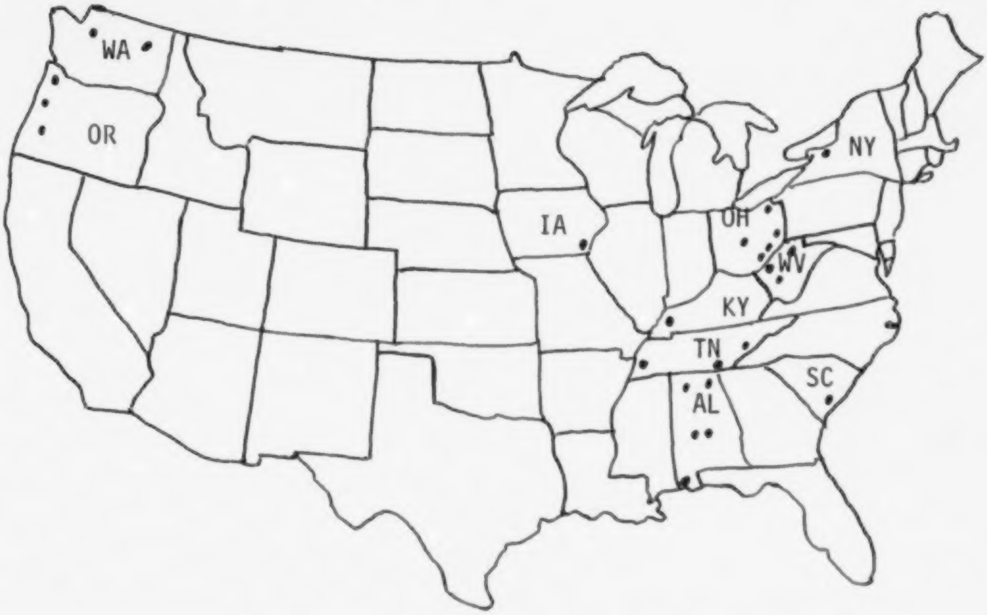
WA
OR
IA
OH
WV
KY
TN
AL
SC
NY

Figure 1. Location of submerged-arc furnaces in the United States.

6.0 FERROALLOY MANUFACTURE

This section contains a brief description of ferroalloy manufacturing processes. More complete descriptions can be found in the open literature.[1] Ferroalloys are manufactured in submerged-arc furnaces, vacuum furnaces, induction furnaces, and by the electrolytic and exothermic (alumino-silico-thermic) processes. The submerged-arc process predominates and is the main subject of this report.

6.1 SUBMERGED-ARC FURNACE

Almost all furnaces of this type are of the same general design shown schematically in Figure 2. The furnace shell is typically cylindrical and constructed of steel. The interior walls are lined with refractories or carbon bricks. One or more tapholes in the furnace shell are provided for removing product and slag.

Typically three carbon electrodes extend into the furnace to within a few meters of the furnace bottom. Vertical movement of these electrodes is possible and is used to partially control power input to the furnace. Feed materials are added to the furnace on an as-needed basis so that the furnace is filled at all times. Power is supplied to the furnace through the carbon electrodes. Most reactions (smelting) occurs in a limited region near the tip of the electrodes. The power supplied is sufficient to produce the alloy in a molten state. The reduction reactions which occur in the furnace produce large quantities of carbon monoxide (from the carbon based reductants added) as well as other gases, including moisture from the charge materials, decomposition products of the feed materials and intermediate products of reactions. The gases rising through the furnace charge contain fume from the high temperature region and also entrain finer size constituents of the charge.

In open-type furnaces (no top cover) the escaping gases burn on the surface of the charge. These gases are collected and cleaned in a variety

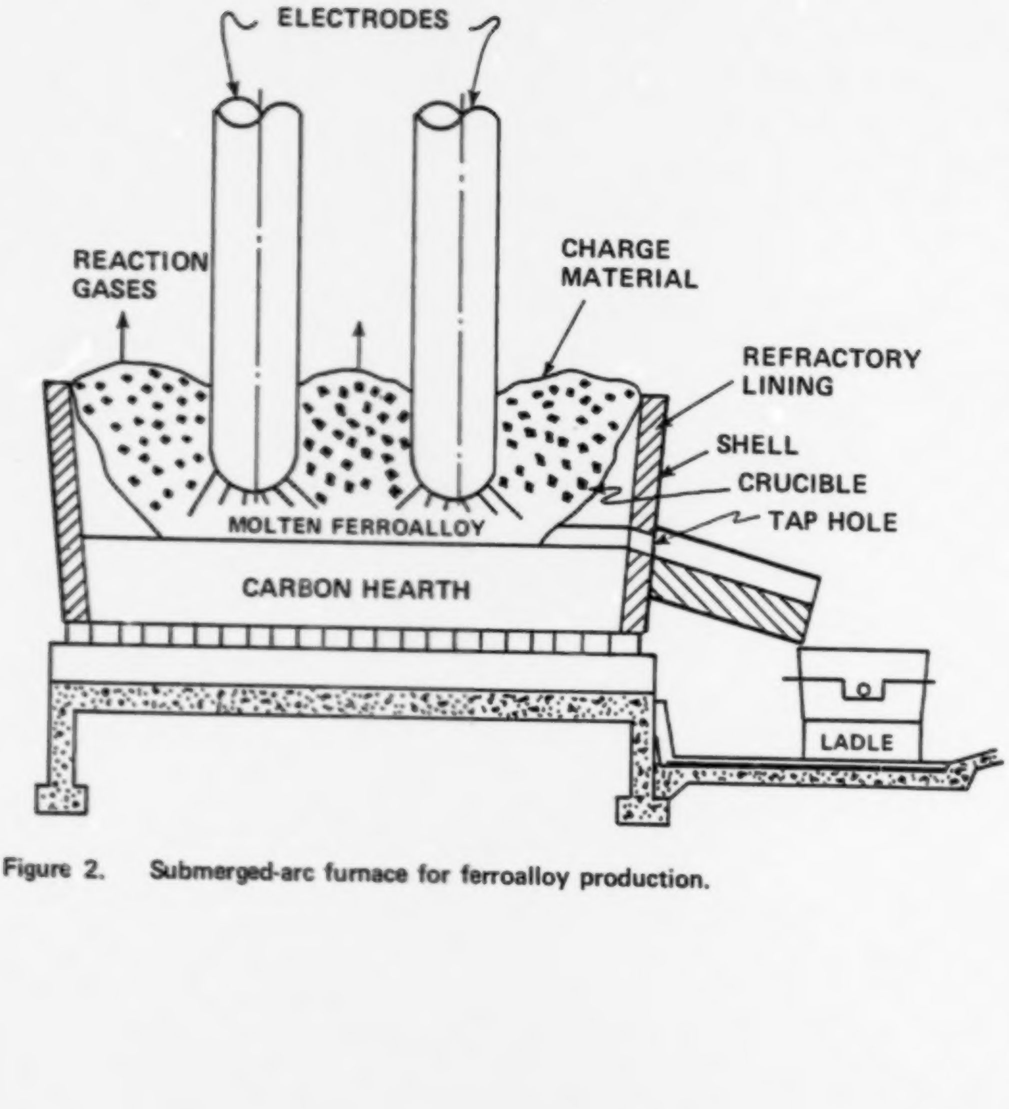
ELECTRODES
REACTION GASES
CHARGE MATERIAL
REFRACTORY LINING
SHELL
CRUCIBLE
TAP HOLE
MOLTEN FERROALLOY
CARBON HEARTH
LADLE

Figure 2. Submerged-arc furnace for ferroalloy production.

of pollution control devices. In covered furnaces no (or limited) combustion normally occurs under the cover, and the gases are cleaned in scrubbers and then flared.

Tapping (withdrawal of product) occurs at either preset time intervals or after a specified power consumption. The molten alloy is collected in ladles, any finishing reactions completed, and the alloy poured into molds to cool before being crushed and graded.

6.2 VACUUM AND INDUCTION FURNACES

Vacuum furnaces are used primarily to produce low carbon ferrochrome from the high carbon alloy produced in the submerged arc furnace although other type products are also produced. The crushed alloy or other feed material is placed in a large vacuum chamber and heated to near its melting point under a vacuum. The carbon in the alloy reacts with oxygen (from silica or chrome oxide) and is removed as carbon monoxide by steam ejectors. Chamber heating is by electrical resistance elements.

Induction furnaces produce small tonnages of specialty alloys by remelting the required materials.

6.3 ELECTROLYTIC PROCESS

Electrolytic processes are used to produce very high purity chromium and manganese. A solution of the desired metal is prepared, and low-voltage direct current is passed through the solution. The product is produced as a deposit (2 cm thick) on the cathode. The feed material for the process may be alloy from the submerged arc process, high metal content slags, or ores. Feed preparation for ores may include calcining and leaching. There is minimal air pollution from the process, but some treatment of the metal containing wastewaters and sludge is usually required. More detailed discussion of this process can be found in reference 4.

6.4 EXOTHERMIC PROCESSES

In the exothermic processes, molten alloys are blended with silicon or aluminum as the reducing agent. These materials react with oxygen in the alloy and generate considerable heat. For example, to produce low carbon ferrochrome (LCFeCr) by silicon reduction, the following steps are employed.

Chrome ore and lime are fused to form the melt. A precise amount of ferrochrome silicon alloy is then added. The reduction reaction is rapid and produces LCFeCr and a calcium silicate slag. Further refining and reaction steps may be employed to recover the metal values. For about 5 minutes per heat, the elevated temperature and strong agitation occurring in the reaction mixture produces particulate emissions with characteristics similar to those from the submerged arc furnace.[1]

6.5 PHYSICAL CHEMISTRY OF THE SUBMERGED-ARC PROCESS

A detailed discussion of the physical chemistry of ferroalloy production is beyond the scope of this project. More information can be obtained from the cited references.[1,13] A brief overview of the process is presented below.

The raw materials used are, depending on product made, usually quartz (or some other form of silicon), ores (manganese, chrome, etc.), scrap iron, and reducing agent (coal, coke). Wood chips, which are added primarily for porosity within the furnace charge are sometimes added (principally to high silicon alloys) and can be considered a reductant.

The purpose of the reducing agents is to remove oxygen from the metal oxides so that the molten metal can accumulate in a pool in the bottom of the furnace. Before this reaction can take place, the feed material must be raised to a high temperature. This is accomplished by the conversion of electrical energy to heat as the electricity flows from the electrodes through the charge material. Temperatures in the lower levels of the reaction zone may approach 3650°C (6600°F).

The simplified equation below illustrates the reactions occurring in the production of 50 percent FeSi.

$$2\ SiO_2 + Fe_2O_3 + 7\ C \rightarrow 2\ FeSi + 7\ CO$$

As can be seen, a large quantity of carbon monoxide is produced in the process.

7.0 SUBMERGED ARC FURNACES

Included in this section are descriptions of the different types of submerged-arc furnaces, some of the advantages and disadvantages of each type, and a discussion of the potential pollution aspects of each type.

7.1 FURNACE TYPES - ADVANTAGES AND DISADVANTAGES

The basic design of the furnace shell, as described in Section 6, is very similar for all ferroalloy submerged arc furnaces. Furnace types referred to in this report, and consistent with industry terminology, are categorized primarily by the type of furnace top cover used. There are four basic types of furnace top covers: Totally open, close hooded, mix-sealed, and sealed. Each type has unique operating advantages and disadvantages, both for the production of alloy and for pollution control.

7.1.1 Totally Open Furnaces

This type furnace is the predominant design in use in the United States. There is no cover of any kind on the furnace. Gases rising out of the furnace mix with ambient air and burn on the surface of the raw material charged to the furnace. The gases are then drawn into a collecting hood which typically is 2-3 meters (6-9 feet) above the furnace.

The open furnace system offers several advantages. Since the hood is well out of the way of the furnace top, access to the furnace is virtually unrestricted. This allows ready access with machinery to stoke the furnace charge (drive probes into the material to break up any hard crust or bridges which may form). This is an important advantage when making certain types of alloys (silicon metal, for example) which tend to form solid bridges in the furnace charge. If a bridge is allowed to form, gases produced by furnace reactions can become trapped in the lower region of the furnace. When the bridge breaks or collapses, the rapidly escaping gas can eject raw material and occasionally molten metal from the furnace. These occurrences are called "blows" by the industry. They obviously present a danger to equipment and personnel. Five employees of one plant were killed[14] in an accident of this type (sealed furnace) in 1979.

Another important advantage of the open furnace type is that it allows the spacing between electrodes to be changed without major modifications to the furnace overhead system. Electrode spacing is an important consideration in efficiently producing different families of products. This spacing can usually be varied enough in an open furnace (with some modifications) to allow manufacturing of most ferroalloy types. This is an important advantage in an industry where the demand for various products is variable.

A third advantage is that only one emission control system is required to collect fumes from the furnace. This means fewer pieces of operating equipment that must be built, maintained, and monitored.

There are some disadvantages to the open furnace, however. In order to effectively collect the fumes from the furnace, the hood system must draw in very large volumes of air. Large air handling systems (ducts, fans, scrubbers, or baghouses) must be built. Capital and operating costs for the system can be quite large. Since large volumes of air are drawn into the hoods, flame temperatures are reduced (below that occurring at near stoichiometric air-fuel conditions) and may result in incomplete combustion of some organics. A further disadvantage is that most scrubbers and baghouses are designed to produce a cleaned effluent of a certain quality (i.e., x mg/m^3). Thus, for equivalent effluent quality produced, the mass emissions are larger for the higher air flows.

7.1.2 Close-Hooded Furnaces

In an effort to retain many of the advantages and reduce the disadvantages of the totally open furnace, some companies have installed movable doors or panels between the hood and the furnace top to restrict the air flow. Thus, access to the furnace, for stoking, etc., can be obtained by opening the doors, and there is little restriction to changing electrode spacing. With the doors in place, air flow can be restricted without a decrease in fume capture. The reduced air flow can, however, be both an advantage and a disadvantage. The lower air flow rate means smaller emission control equipment (scrubbers, baghouses) is required and, overall mass emissions should decrease, compared to the totally open furnace. Also, the gas temperature is substantially higher, increasing the probability that the more refractory organics can be destroyed. One company, Chromium Mining and Smelting Company (CHROMASCO) has taken advantage of the high gas temperature by installing a scrubbing system that extracts heat from the gas and uses it, through steam generation, to produce the furnace draft. However, some problems have been noted with the system. A disadvantage of the high temperature that results from restricting the air flow is the extra precautions that must be taken to protect exposed equipment.

7.1.3 Mix-Sealed Furnaces

In this furnace design, a water-cooled cover is installed directly on the furnace top. There are doors on the side of this cover to allow some access for observation but very limited access for stoking. Feed materials (mix) are added to the furnace through the annular spaces around the electrodes which pass through the cover. Sufficient mix is kept around the electrodes so that, as long as a slight negative pressure is maintained beneath the cover, little furnace gas escapes the furnace cover, and little air is drawn into the furnace.

An advantage to this design is that the very low gas volumes exiting the furnace allow the use of much smaller pollution control equipment than for open furnaces and thus, lower operating expense. Although a secondary hood over the furnace is required to collect gas and fumes escaping the cover (primarily from the mix-seals), the relatively low air volume from this source can be handled in a baghouse which has low capital and operating cost. The total cost of the two systems, however, may be as much as for a similar size open furnace. A second advantage is that the furnace gases can be used, after scrubbing, as plant fuel. This option is seldom exercised in the United States, however, and most gases from the covered type furnaces are flared. Covered or mix-sealed furnaces are used primarily for pollution control purposes where there is little danger of violent furnace "blows."

Disadvantages to the furnace are that two fume collection systems are required, stoking the furnace is virtually impossible, and that combustion of the organic matter generated by the furnace is minimal. This latter problem could be a major disadvantage of the nature of the organic matter generated as shown in later sections.

7.1.4 Sealed Furnaces

Sealed furnaces are similar to the mix-sealed type. The major difference is that mechanical seals are used around the electrodes and the feed mix is added to the furnace through sealed chutes. The furnace sealed in this manner allows virtually no gas and fume to escape from the furnace cover, and only a minimal secondary hood air flow is required. Also, there is virtually no air leakage into the furnace and, thus, combustion of furnace gas does not occur. The cleaned gases are flared.

Reduced escape of gas and fume from the furnace cover and lower cover temperature (less under cover combustion) are the only identified additional advantages of the sealed designs. Because of operational inflexibility and other problems, the industry trend is away from the covered type furnace.

7.2 ANCILLARY EQUIPMENT

After sufficient alloy has been formed in the furnace, it is tapped (metal withdrawn) through a hole in the side of the furnace. Normally this hole is plugged with carbon paste. A tap is started by making holes in the plug (usually with a small cannon). The hole may be enlarged with poles or oxygen lances. The molten metal flows down a carbon lined trough into the ladle. Fumes generated in from this area can be quite heavy, especially during the first few minutes of the tap. Several types of tapping fume controls are in use and include fixed hoods, hoods that swing into place, and mobile hoods. Design of these control systems is difficult since provision must be made for access to the ladles by overhead cranes. Emission control in the area is, therefore, usually poorer than for gas and fume from the furnace.

The filled ladle may have additional material added to produce a specified product. Very little additional refining or treatment occurs in the ladle.

The ladle is then carried by overhead crane to the cooling area where the alloy is poured into carbon lined molds and allowed to solidify. Fumes produced in this area are noticeable but not substantial. Collection devices are not used and the fumes rise to the top of the building and exit through roof monitors.

The solidified alloys are removed from the molds, crushed, sized, and placed in storage bins. Most plants have dust collection equipment over the crushing operation. Capture of the dust from crushing is usually by baghouse.

7.3 POLLUTION POTENTIAL

The pollution potential of the submerged arc ferroalloy furnace will be discussed in terms of organic and particulate matter for the different furnace types and different emission control options.

Because of the raw materials used (coal, coke, woodchips, etc.), the chemically reducing atmosphere inside the furnace, and the high temperature, gases leaving the furnace (before any combustion) theoretically contain substantial amounts of organic matter, inorganic fumes, and entrained particulate matter. The amounts of these materials should vary with product type since this dictates operating temperature and percentage of reductant used. An indication of the expected variation for particulates can be seen in Table 15[1] which summarizes the potential particulate emissions if the furnaces were uncontrolled.

The actual amount of pollutants generated by the furnace, however, may also depend on the type of furnace cover used and, possibly, other operating factors.

7.3.1 Open Furnaces

In an open furnace, the gases burn vigorously on the surface of the charge as they leave the furnace. This combustion tends to destroy the CO, H_2, and other combustible gases. It also destroys most organic compounds and converts most metallic components into their oxidized form. Totally uncontrolled emissions from these furnaces would, therefore, not be expected to have high concentrations of low molecular weight gases or organics but could pose problems with respect to particulates and inorganic components. This is considered in some detail in a previous study[1] and is confirmed by the analysis presented in Section 12 for furnace B-1. Fume and particulate matter generated by the furnaces are predominantly submicron as shown by test results presented here and elsewhere.[1,15]

The amount and types of pollutant discharged and the media in which they impact the environment may vary with the type of pollution control

TABLE 15. POTENTIAL PARTICULATE EMISSIONS (1971)[1]

Product	Uncontrolled emission factors, lb/ton alloy
Silicon alloys	
CaSi	1,343
Silicon metal	1,200
65-90 percent FeSi	673
50 percent FeSi	446
Silvery iron (15-22% FeSi)	116
Chrome alloys	
FeCrSi	831
HC FeCr	335
LC FeCr	60
Manganese alloys	
HC FeMn	335
LC FeMn	133
FeMnSi	315
SiMn	219
Other	
CaC_2	100

equipment. Since gas volumes from open furnaces are very large, most plants rely on baghouse filtration. There should be little impact from aqueous effluents when this method is used. However, at least one plant slurries the dust captured in the baghouse and transports this slurry to the wastewater ponds. There is a possibility that some metals and organics may leach out of this dust and impact the final plant wastewater discharge. The major impacts would be particulate emissions to the air and possible leaching from solid waste disposal sites. Baghouses are generally considered to capture 99+ percent of the particulate entering. It is not unusual, however, to see large quantities of dust in the areas surrounding the baghouses. This dust arises because of leaks in the mechanisms transferring the collected dust to trucks that remove it from the site. Some of this dust may become resuspended when there is a significant wind velocity. The collected dusts from the baghouse are typically landfilled on site or nearby company property. The possible hazards surrounding this practice are of concern and are discussed in a separate section of this report.

The collection efficiency of the baghouse for organics is not expected to be very good and depends on the organic concentration in the gas phase and baghouse temperature. Theoretical studies[16] have shown that the equilibrium vapor pressure of benzo(a+e)pyrene can be described by:

$$\text{Log } \rho = -\frac{6182}{T} - \text{Log } T + 25.089,$$

where ρ is the vapor concentration in nanograms per cubic meter and T is in degrees Kelvin. The Air Health DMEG value for benzo(a)pyrene (B(a)P) is 20 nanograms/m^3. Thus, if the baghouse operates at above 17°C (63°F), no collection of B(a)P would occur if the concentration in the furnace gas was at or below 20 nanograms/m^3. Actually, most baghouses operate between 100-150°C so that no collection of B(a)P would occur if its concentration in the furnace gas was as high as 0.89 (at 100°C) or 71.3 (at 150°C) milligrams/m^3. There is no indication that these concentrations exist in the open furnace gas. The calculations are presented to show that bag filters have a low potential for capture of organics generated. It should be noted that many non-ideal effects, including preferential adsorption on particulate, can substantially reduce the amount of organic vapor actually passing through the baghouse.

Scrubbers are used on some open furnaces. This method is not in wide use primarily because of the increased (compared to baghouses) energy requirements (higher pressure drop) but also because scrubbers require some type of wastewater treatment. Average water usage for scrubbers is 20,000 liters (5,300 gals.) per Mw-hr of furnace power.[3] A great deal of data on the wastewater from ferroalloy plants appears in Reference 3. For open furnaces, suspended solids are the primary water pollutant although low concentrations of the dissolved metals (manganese, chromium) are also present, depending on the product being made. The industry seems to have little difficulty in handling these wastewaters since simple clarification or solids settling in ponds effectively removes the suspended solids. There does appear to be some concern with possible leaching of metals from these solids, however, and this subject will be covered in the section on solid waste.

The effectiveness of organic removal by scrubbers should theoretically be higher than that obtained by baghouse since the gas temperature is significantly lower. The data presented later for the plant tests show that organic matter collection effectiveness by scrubbers is less, and sometimes substantially so, than for particulate collection.

7.3.2 Covered Furnaces

Generally, very little combustion occurs under the cover of these type furnaces. The extent of combustion does vary, however. There is at least one covered (mix-sealed) furnace in which substantially complete combustion occurs under the cover (designated in this report as A-1). The limited combustion which occurs in the covered furnaces means that the gases going to the pollution control equipment are essentially the same as generated by the furnace. The gas, therefore, contains high concentration (20-90 percent) of carbon monoxide, some carbon dioxide, and hydrogen and various types of organic matter in addition to the fume and particulate.

The high CO content requires that attention be paid to the hazardous and explosive potential of the exhaust gas. The collection and control systems are well sealed and work area ventilated. Primarily because of the explosion hazard, all covered furnaces in the United States use scrubbers to control the gases and fumes withdrawn from under the furnace cover.

The high energy scrubbers effectively remove particulate matter from the furnace gases. Medium and low energy (disintegrator) types are less effective in particulate removal. The particulate matter does contain a significant amount (1-4 percent indicated by this work) of organic matter, some of which may be carcinogenic. The gas leaving the scrubber goes to flares. However, some flares do not burn continuously. From visual observation during site visits and during test work, it appears that some flares on mix-sealed furnaces burn less than 75 percent of the time. This can be due to operational factors (flare ignitors don't work), to low CO content in the gas because of high oxygen content in charge materials (manganese alloys), or to some undercover combustion. The effectiveness of flares for destroying the higher molecular weight organics is questionable since test data show that organics survive even in the gases from open furnaces which burn vigorously. At present there is no known accurate or reliable method for sampling emissions from flares.[17]

The scrubber discharge water contains a high concentration of suspended solids and organic matter. There is a strong but unproven indication that much of the organic matter is adsorbed on the particulate. Some organics, phenols for example, are sufficiently water soluble that water treatment is employed at many plants for their destruction. Wastewater treatment at most plants consists of solids removal (by settling in ponds or by filtration) before any chemical treatment of the water. Thus, the solids, and the organics contained therewith, receive essentially no treatment. Disposal of the scrubber sludge is either by allowing the settling pond to fill (and building new ones as required) or dredging the solid out and putting it in a landfill. We have found no evidence that any of the ponds or landfills are lined or have impermeable soil conditions. The industry has expressed the opinion that the sludges are essentially self-sealing. This will be discussed in the section on solid waste disposal.

The high molecular weight fused aromatic compounds have very low water solubilities.[18] Typical solubility values are 1.4×10^{-4} mg/L for coronene, 3.8×10^{-3} mg/L for 3,4-benzopyrene, and 0.26 mg/L for fluoranthene. Studies have shown that a combination of filtration and chlorination are effective[19] in significantly reducing the concentration of PNAs in water. These data imply that with effective treatment, wastewater from ferroalloy manufacture can be very low in PNA content. Chlorination may, however, also produce other objectionable compounds.

Gas and fumes also escape from the cover of the mix-sealed furnaces. Most occurs as a result of furnace gases escaping past the mix-seals. Under normal conditions, small amounts of gas escape the seals and wisps of fume can be seen rising from the cover. During "blows" or periods when the mix around the electrodes is low, large volumes of gas escape the seals and carry fumes and entrained particulate into the secondary emission control system. In this latter case, the gas escaping the seals is usually burning. There are indications from this work and from others[1,2] that significant amounts of particulate can escape from the covers. All furnaces are equipped with hoods to collect these gases and particulates. Most of these systems also capture the particulate in a baghouse. Concern for the pollution potential from this area is primarily for particulate matter. It is suspected that some organics are contained in these gases and fumes; however, the total mass should not be high since the gas usually burns during periods of heavy gas and fume release from the cover.

7.3.3 Ancillary Equipment

A substantial generation of gas and fume occurs at the tap hole and lip during the initial phase of a tap. These fumes occur as a result of (1) burning the carbon plug out of the tap hole, (2) fumes rising from the hot metal, and (3) vaporization of organics in the carbon used as a lip liner. Further fume generation occurs in this area when the tap hole is plugged (carbon paste injected into the hole) and when the carbon added to the lip is heat cured. Most of these emissions are of short duration and are partially captured by the tap hole emission control system. Fumes not captured exit the building through the roof monitors. Although the organic content of the fumes could be at high concentration and could contain hazardous compounds, the total mass is probably low compared to that in the furnace gas. Most other fume and dust occurring from transfer, cooling, grinding, and packaging of the alloy should be primarily metallic components with analysis similar to the alloy being produced.

8.0 SOLID WASTE DISPOSAL

The Ferroalloy Association estimates[20] that about 362,875 tonnes (400,000 tons) of solid waste (dusts, sludges, and slag residues) are produced annually at the current annual production rate of 1.45 million tonnes (1.6 million tons) of the various chromium, manganese, and silicon ferroalloys. They estimate that about 30 percent of this waste material may be composed of those designated wastes specifically listed as hazardous by proposed section 3001 of the Resource Conservation and Recovery Act (RCRA). "Conceivably,[20] all ferroalloy wastes could be classified as hazardous by the proposed extraction procedure, although limited testing has shown that slags, in general, are very insoluble and would be classified as nonhazardous under proposed section 3001 criteria."

The average quantity of waste generated is about 9072 tonnes (10,000 tons) per year per plant but is quite variable and depends on plant size and product mix. About 40 percent of this waste is generated in Ohio and West Virginia, 30 percent in Alabama and Tennessee. Smaller quantities are generated in Oregon, Washington, South Carolina, Iowa, and New York.

The dusts and sludges generated are primarily submicron particles, consisting of oxides of silicon, manganese, chromium, calcium, magnesium, and other elements in widely varying proportions depending on the product being made. Slags are vitrified oxides of essentially the same elements. As shown in other sections of this report, the sludges, particularly from covered type furnaces, may also contain various types of organic compounds including polycyclic aromatic hydrocarbons, some of which are known carcinogens.

Currently, these wastes are disposed of by inclusion in dedicated landfills or deposition in lagoons. Slags, in particular, may be stocked on plant property in anticipation of future discovery of recycle methods. Waste mounds in controlled disposal areas can approach 76.2 meters (250 feet) in depth while sludge depth in lagoons may be as much as 10.7 meters (35 feet).

The Ferroalloy Association estimates that 85 percent or more of the wastes are disposed of by these techniques. Less than 15 percent is recycled, reclaimed, or sold.

To the best of our knowledge, all waste is disposed of in unlined (nonsealed) areas. Industry data indicate that the sludges and dusts have saturated hydraulic conductivity "K" values ("permeability") of 10^{-4} to 10^{-8} cm/sec, equivalent to the range of medium permeability soils through some of the best naturally occurring clays. The industry feels, therefore, that these materials act as their own barriers to rainwater and surface water intrusion, i.e., that the wastes are "self-sealing."

Estimated current (1980) solid waste disposal costs are $3 to $8 per ton (907 kg). Industry estimated that an additional cost of $8 to $25 per ton would be required to meet the requirements of proposed section 3004 of RCRA. This did not include the cost of upgrading present disposal sites. Recent (1981) data suggest disposal costs of over $80/ton for any waste classified as hazardous (Section 3001 of RCRA).

The Ferroalloy Association and EPA (Office of Solid Waste) have been negotiating for several years as to whether the industry's solid waste should be classified as hazardous. Calspan Corporation surveyed the industry (as part of a larger study) in the mid 1970's and assessed the hazard potential of the solid wastes.[21] This report concluded that many solid wastes produced by the industry are hazardous (only metals leaching was considered) and that disposal practices are not adequate. The industry responded[22] that the study was superficial, lacked an understanding of the industry, and was, therefore, of little value. The industry particularly criticized the method used to determine leaching, use of isolated, non-representative samples, inclusion of ferromanganese production by blast furnace, improper analysis of waste disposal alternatives, and impractical technical proposals. The industry has submitted their own data to EPA on metals leachability (Table 16)[23] and on the results of monitor well tests for typical landfills and unlined lagoons[20] (Tables 17, 18). The data from Table 16 show that leachate from emission control dusts exceed the 10 times EPA National Interim Primary Drinking Water Criteria for classification as hazardous for at least one metal when the leaching solution contains only water or also contains acetic acid (extraction procedure (EP) of 9/12/78

TABLE 16. THE FERROALLOYS ASSOCIATION ENVIRONMENTAL COMMITTEE SOLID WASTE TASK FORCE LEACHATE TESTING RESULTS[23]

	As	Ba	Cd	Cr	Pb	Hg	Se	Ag
			Leachate concentrations, mg/L					
Waste from FeMn Production								
EPA EP Using H_2O Only								
Emissions Control Dust (Sx #1)	.10	<.10	<.10	(1.4)	(2.0)	.001	-	-
Emissions Control Dust (Sx #2)	.01	<.10	(.30)	(1.0)	(7.6)	.001	.01	-
Slag (3/8" x 1/4")	.04	<.10	<.10	<.10	<.10	<.001	<.01	-
Slag (200 mesh)	<.01	<.10	<.10	<.10	<.10	.005	<.01	-
EPA EP per 9/12/78 Draft								
Emissions Control Dust	-	<.10	<.10	.40	(14.0)	-	-	-
Slag - Co. B	-	7.40	<.10	<.10	.30	-	-	-
EPA EP per 3/6/78 Draft								
Slag - Co. A	.01	6.5	.01	.03	.02	-	<.002	-
Slag - Co. E	<.02	4.1	.09	<.01	.02	<.002	<.005	<.01
Waste from FeCr production								
EPA EP Using H_2O Only								
Emissions Control Dust (Sx #1)	.05	<.10	<.10	(.65)	<.10	.004	<.01	-
Scrubber Dust (Sx #2)	-	<.10	<.10	<.10	<.10	-	-	-
Slag - Co. B	.05	<.10	<.10	<.20	<.10	.005	<.01	-
Slag - Co. C	.001	.04	<.01	<.01	<.01	<.001	<.01	<.001
EPA EP per 9/12/78 Draft								
Scrubber Dust (Sx #2)	-	<.10	<.10	<.10	<.10	-	-	-
EPA EP per 3/6/78 Draft								
Slag - Co. A	.01	.51	.01	.04	.01	-	<.002	-
Slag - Co. B	<.01	<.10	<.10	<.10	<.10	.003	<.01	-
Slag - Co. C	<.01	.66	.001	.01	<.01	<.001	<.01	<.001

TABLE 16. (Continued)

			Leachate concentrations, mg/L					
	As	Ba	Cd	Cr	Pb	Hg	Se	Ag
Waste from FeCrSi Production								
EPA EP Using H_2O Only								
Emissions Control Dust	-	<.10	<.10	(2.0)	<.10	-	-	-
Slag - Co. C	0.001	.04	<.001	<.01	<.01	<.001	<.001	<.001
EPA EP per 9/12/78 Draft								
Emissions Control Dust	-	<.10	<.10	(2.4)	.30	-	-	-
EPA EP per 3/6/78 Draft								
Slag - Co. C	<.001	.66	.001	<.01	<.01	<.001	<.001	<.001

Note:
1. ( ) around a value indicates a concentration greater than 10 x DWS.
2. Test data based on H_2O only signifies the same ratio of H_2O to solids as in EPA EP, but no acetic acid is added as per the 3/6 or 9/12/78 draft procedure.
3. Company code in this table is not the same as for the rest of this report.

TABLE 17. DATA FROM A FERROALLOY COMPANY'S MONITORING WELLS AT A TYPICAL LANDFILL[20]

Location		Parameter concentrations mg/L			
	Ba	Cd	Cr	Pb	Hg
Test #1					
Upgradient Groundwater Background					
Well #3	.25	<.005	.02	<.03	<.0005
Well #4	.20	.03	.02	.08	<.0005
Downgradient of Landfill					
Well #1	.10	.01	<.01	.08	
Well #2	<.05	.10	.02	.06	
Well #5	<.05	.005	.01	.03	
Test #2 (1 month after #1)					
Upgradient Groundwater Background					
Well #3	.05	<.005	.03	.07	<.0005
Well #4	.15	.010	.01	.05	<.0005
Downgradient of Landfill					
Well #1	.01	.01	<.01	.08	
Well #2	.05	<.005	<.01	.10	
Well #5	.05	<.005	.01	<.03	
Test #3 (2 months after #1)					
Upgradient Groundwater Background					
Well #3	<.05	.005	.03	.08	<.0005
Well #4	.05	.010	.02	.08	<.0005
Downgradient of Landfill					
Well #1	.15	.01	.01	.05	
Well #2	.10	<.005	.01	.03	
Well #5	.05	.008	<.01	.04	

Note: All data derived from independent laboratory determinations.

TABLE 18. DATA FROM A FERROALLOY COMPANY'S MONITORING WELLS SURROUNDING AN UNLINED DISPOSAL LAGOON[20]

Location	Distance from Lagoon (in feet)	As	Parameter concentrations, mg/L Ba	Pb	Cd	F
Test #1						
Lagoon analysis		.50	.042	.030	.020	3.5
#1 Well	100	<.02	.042	.085	ND	.06
#2 Well	500		.037	.105	.020	.05
#3 Well	200		.029	.190	.020	<.05
#4 Well	100		.043	.085	ND	.06
#5 Well	1,600		.036	.090	ND	<.05
Test #2						
Lagoon analysis	----	.50	.054	.160	ND	4.8
#8 Well	375	.02	.060	ND	ND	.82

Note: ND means no determinable amount.
These data derived from independent laboratory determinations.

and 3/6/78 drafts. See also Federal Register, Volume 43, No. 243). Neither scrubber dust (sludge) nor slags exceeded this criteria. The industry feels that the test is not representative of actual dust characteristics. The industry claims the dust forms a hard, monolithic surface layer when exposed to water, and, therefore, any additional precipitation will run off rather than being adsorbed and transmitted to groundwater. They also claim that the dusts are quite alkaline and would, therefore, inhibit leaching most metals. The data from Table 16 indicates some metals still leach out. The data in Tables 17 and 18, however, do show that any leachate from at least two disposal sites has minimal effect on the groundwater quality for at least five elements of concern.

Previous studies have not addressed the question of the presence of organic matter. The data developed in this study indicates that dusts from open type furnaces generally contains less than 0.1 percent organic matter and that less than 10 percent (usually less than 3 percent) of this organic is polycyclic organic matter (POM). Analysis of the organic matter suggests possible low concentrations of carcinogens. Scrubber sludges from covered furnaces, on the other hand, may contain up to 8 percent organic matter. POM content may be as high as 65 percent of the organics. Detailed analysis (see later sections) indicate that these sludges are likely to contain significant concentrations of polynuclear aromatic hydrocarbons (PNA), including the known carcinogens, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and others.

Typical disposal procedures for these sludges is settling in unlined lagoons which may either be allowed to completely fill with solids or the solids may be dredged out and landfilled. Since high concentrations of PNA are likely in the scrubber water and sludge and since previous work[19] indicates that as much as 90 percent of this type material can be adsorbed on suspended particulate, it is likely that the sludges in the lagoons and landfills, especially that from covered furnaces, contains high concentrations of PNA and may exceed the minimum acute toxicity effluent limits for solid wastes. Data in the section on Screening Samples strongly indicate this possibility since a number of the samples are for materials that would be landfilled without further treatment.

The question then is whether or not current disposal techniques provide adequate protection from leaching the organic materials into groundwaters. We first note that the aqueous solubility of PNAs is essentially unaffected by solution pH. Thus, the fact that the wastes may be alkaline will have no effect on leachability, and the use of acetic acid in the extracting solution also would be expected to have minimal effect. The possibility does exist that the PNAs are preferentially adsorbed on the solids, and the concentration in a leaching solution would be less than the true solubility in pure water. This can only be confirmed or denied by testing the actual wastes involved. The possibility also exists that the wastes are "self-sealing" as indicated by the industry. Since it was beyond the scope of this work to investigate the above factors, the question cannot be unequivocably answered. It appears, however, that a potential exists for leaching hazardous organics from the sludges and that, in many instances, the disposal methods in use may not provide adequate protection against contamination of groundwaters.

9.0 POM DEGRADATION

In this section, the formation of POM (polycyclic organic matter) in ferroalloy furnaces is discussed and results of research on possible degradation or removal mechanisms are presented. Also discussed are the implications of data obtained in this study for control of POM emissions.

9.1 RATE OF POM FORMATION BY FERROALLOY FURNACES

As a guide for use in evaluating the POM calculations which follow, a calculation of the total POM emitted by all coke ovens (uncontrolled) in the United States is presented. Coke ovens are considered by EPA to be major emitters of POM compounds. Control methods are oriented toward operational changes that contain the POMs within the ovens and byproduct plant whenever possible. Approximately 0.91 kg (2 lbs) of benzene soluble organics (BSO) are emitted from coke ovens (not including quenching) for each 0.91 metric tons (2000 lbs) of coal coked.[24] Approximately 0.5-5 percent (wt) of the BSO is POM.[25] Total coal coked in these ovens each year is about 63.5×10^6 metric tons (70×10^6 tons). Thus, total POM emissions (uncontrolled) from coke ovens is approximately:

$$63.5 \times 10^6 \text{ Mg coal/yr} \times 1.0 \text{ kg BSO/Mg coal} \times (0.005\text{-}0.05 \text{ kg POM/kg BSO})$$
$$= 317{,}500 - 3{,}175{,}000 \text{ kg/yr } (0.7 - 7 \times 10^6 \text{ lbs/yr})$$

Data from a previous study[6] of a sealed ferroalloy furnace producing FeMn indicate that the mass of POM generated at full load would be about 24,954 kg/yr (55,014 lbs/yr) or 1,442 kg/yr (3,179 lbs/yr) per Mw of capacity. Since there is about 212 Mw of installed covered (sealed or mix-sealed) capacity, the total POM generated by covered furnaces assuming an operating factor of 80 percent is about 244,560 kg/yr (539,170 lbs/yr) if all covered furnaces generated POM at this rate.

The POM generation rate of the open and covered furnaces tested in this study (excluding furnace A-1) were calculated assuming the aromatic hydrocarbon and halogenated aromatic hydrocarbon categories are all POM and are the only categories containing POM. Neither assumption is likely to be entirely correct. The calculations, which follow, indicate that covered furnaces may generate POM at the rate of 1,230 to 11,080 kg/yr (2,710 to 24,430 lbs/yr) per megawatt of furnace power or 208,800 to 1,878,800 kg/yr (460,300 to 4,120,000 lbs/yr) for all U.S. furnaces of this type. Calculated POM generation rates of open furnaces are 100 to 900 kg/yr (220 to 1,980 lbs/yr) per megawatt of furnace power or 134,500 to 1,210,500 kg/yr (296,500 to 2,668,700 lbs/yr) for all U.S. furnaces of this type.

These calculations indicate that covered furnaces, which make up only 14 percent of the industry capacity, may actually generate more POM (61 percent of the total estimated nationwide generation rates) than the open furnace. The total estimated nationwide POM generation rate from all U.S. furnaces is 343,300 to 3,089,300 kg/yr (756,850 to 6,810,700 lbs/yr) or about the same as estimated for coke ovens.

Calculation of POM Generation Rates

A. Open Furnaces

Furnaces included in this calculation are A-2 and B-1.

1. A-2

Furnace power level during test -- 15.8 MW
Stack gas flow rate -- 3,355.4 DSCMM
Scrubber water discharge rate -- 2.27 m^3/min
POM in scrubbed gas -- 3.7 mg/m^3 (combined aromatic hydrocarbon and halogenated aromatic categories)
POM in scrubber water -- 3.66 mg/L

POM in gas =
$(3.7 \times 10^{-6}\ kg/m^3)(3,355.4\ m^3/min)(60\ min/hr)(24\ hr/day)(365\ days/yr) \div 15.8\ MW = 413\ kg/yr/MW$ of capacity

POM in scrubber water
$(3.66 \times 10^{-6}\ kg/L)(1,000\ l/m^3)(2.27\ m^3/min)(60)(24)(365) \div 15.8 = 276.4\ kg/yr/MW$ of capacity

Total A-2 = 413 + 276.4 = 689.4 kg/yr/MW of capacity.

2. B-1

Furnace power during test -- 48.4 MW
Stack gas flow rate -- 5,749.8 DSCMM
POM in furnace gas -- 4.49 mg/m^3

POM in gas =

$(4.49 \times 10^{-6})(5,749.8)(60)(24)(365) \div 48.4 = 280.4$ kg/yr/MW of capacity.

Average POM generation rate for open type furnaces (this calculation assumes that only the open FeMn furnaces generate POM at furnace A-2 rate and that all others are represented by furnace B-2. We suspect this results in a low estimate but it is better than a simple average.)

$$\frac{73 \text{ MW FeMn open}}{1,333 \text{ total open}} (689.4) + \frac{1,260}{1,333} (280.4) = 302.8 \text{ kg/yr/MW of capacity}$$

Range (1/3 to 3) = 100.9 to 908.4 kg/yr/MW of capacity.

Yearly nationwide POM generation rate range (assuming 80 percent operating factor).

(100.9)(1,333 MW of capacity)(0.8) = 134,500 kg/yr
(908.4)(1,333 (0.8) = 1,210,500 kg/yr

B. Mix-sealed Furnaces

Furnaces included are B-2, C-1, C-2.

1. B-2

Furnace power -- 48.0 MW
Stack gas flow rate -- 149.97 DSCMM
POM in scrubbed gas --446.18 mg/m^3
POM in scrubber water -- 146 mg/L
Scrubber water discharge rate --2.27 m^3/min.

POM in gas =
$(446.18 \times 10^{-6})(149.97)(60)(24)(365) \div 48.0 = 732.7$ kg/yr/MW of capacity.
POM in scrubber water =
$(146 \times 10^{-6})(1000)(2.27)(60)(24)(365) \div 48.0 = 3,629$ kg/yr/MW of capacity.
Total B-2 = 732.7 + 3,629 = 4,361.7 kg/yr/MW of capacity.

2. C-1

Furnace power -- 15.5 MW
Stack gas flow rate --156.48 DSCMM
Scrubber water discharge rate -- 1.90 m^3/min
POM in scrubbed gas --197.0 mg/m^3
POM in scrubber water -- 43.8 mg/L

POM in gas =

$(197 \times 10^{-6})(156.48)(60)(24)(365) \div 15.5 = 1{,}045$ kg/yr/MW of capacity.

POM in scrubber water =

$(43.8 \times 10^{-6})(1{,}000)(1.90)(60)(24)(365) \div 15.5 = 2{,}822$ kg/yr/MW of capacity.

Total C-1 = 1,045 + 2,822 = 3,867 kg/yr/MW of capacity.

3. C-2

Furnace power -- 16.8 MW

Stack gas flow rate -- 173.978 DSCMM

Scrubber water flow rate --1.90 m^3/min

POM in scrubbed gas -- 302.86 mg/m^3

POM in scrubber water -- 20.2 mg/L.

POM in gas =

$(302.86 \times 10^{-6})(173.978)(60)(24)(365) \div 16.8 = 1{,}648.5$ kg/yr/MW of capacity.

POM in scrubber water =

$(20.2 \times 10^{-6})(1{,}000)(1.90)(60)(24)(365) \div 16.8 = 1{,}200.7$ kg/yr/MW of capacity.

Total C-2 = 1,648.5 + 1,200.7 = 2,849.2 kg/yr/MW of capacity.

Average POM generation rate for mix-sealed furnaces =

(4,361.7 + 3,867 + 2,849.2) ÷ 3 = 3,692.6 kg/yr/MW of capacity.

Range (1/3 to 3) = 1,230.9 to 11,077.8 kg/yr/MW of capacity.

Yearly nationwide POM generation rate range from covered type furnaces (assuming 80 percent operating factor)

(1,230.9)(212)(0.8) = 208,800 kg/yr

(11,077.8)(212)(0.8) = 1,878,800 kg/yr.

Note that other methods of calculation will likely yield different results (higher or lower) than given here. For example, the aromatic and halogenated aromatic hydrocarbon categories make up 80.6 percent [(294.46 ÷ 365.3) x 100] of the total organic matter recovered by the Level 1 analysis of the SASS train organic module for the C-2 furnace test (Table 83). If one multiplies this by the 1.7934 kg/hr of organics for the SASS module given in Table 81 and

8,760 hr/yr, one obtains (0.806)(1.7934)(8,760) ÷ 16.8 = 753.7 kg/yr/MW of capacity, substantially less than given previously (POM contained in the dust collected was included in the previous calculation but would not measurably affect the comparison now being made). These differences occur because the total organic recovered from the seven liquid chromatography (LC) fractions may be greater than or less than the organic determined before LC fractionation. Because it is uncertain which, if either, organic determination is correct, the calculations used to estimate POM are based on the LC fraction determination which generally yield the highest POM estimates. This is consistent with the "worst case approximation" philosophy of the Level 1 methodology.

9.2 POM BEHAVIOR IN AQUEOUS SYSTEMS

Some POM generated by ferroalloy furnaces are captured by baghouses and scrubbers. This section deals with the behavior of POM in the scrubber discharge water and any baghouse dust which is slurried.

Polycyclic organic matter (POM) in aquatic systems may be removed or transformed by several means. They may evaporate into the air. They may be broken down by reaction with light. POM tends to adsorb on the surface of particulate solids present in the water. Thus they may be removed by sedimentation of suspended solids and by adsorption onto previously settled sediment. Microorganisms and other aquatic life can ingest and transform the POM present in the water.

To assess the environmental consequences of aqueous discharges of POMs, not only should the discharge rate be considered, but also those processes which degrade the pollutants. Laboratory studies have been used to investigate the mechanisms of POM removal.

Two such research programs are discussed below:

Oak Ridge National Laboratory

Research to identify and measure the processes transforming POM is currently underway at the Environmental Sciences Division of Oak Ridge National Laboratory (ORNL) under a Department of Energy contract.[26] Preliminary measurements have been made of POM removal by several different mechanisms. The ORNL workers hope to conduct field tests and confirm their models of POM behavior so that, ultimately, the fate of POM can be predicted from a description of the aquatic system in question. The following material is based on reports provided by ORNL.[27-36]

The adsorption of anthracene onto typical sediments was studied. (Anthracene was chosen as a representative POM which has an intermediate molecular weight, is not carcinogenic, and is available in a carbon-14 labeled form.) When anthracene is added to water containing suspended particles, it is adsorbed on the surface of the particle. In this way, the POM associated with the particles increases, while the level of dissolved POM in the water phase decreases. Dead microorganisms and suspended organic material were found to have a much higher affinity for POM adsorption than do inorganic particles. The partition coefficient, K_d, was used as a convenient measure of the tendency of the POM to adsorb. (It is calculated by dividing the POM content of the solid by the POM content of the liquid. The larger K_d, the more POM will be adsorbed from the water onto the solid surface.) K_d for anthracene onto dead yeast cells was found to be about 20,000 ppm on particulate/ppm in water. K_d for inorganic clays and silt is much lower by at least one and as much as two orders of magnitude.

In slow-moving, turbid waters, particulates which have adsorbed POM settle by gravity. This mechanism has the net effect of removing dissolved POM from the water and then depositing it on the bottom as sediment. The rate of this removal can be related to the stream depth, the amount of particulate present, and the size and density of the suspended solids. In a related mechanism of POM transport, the sediment layer already at the stream bottom can adsorb POM directly from the water. As more POMs are adsorbed by the bottom sediment, the surface layer of sediment will become saturated if POMs are not removed from the sediment by some other means.

In some steams, microbial degradation will convert POM in the bottom sediment, and thus result in some equilibrium between adsorption and degradation. The rate of microbial degradation in sediment was found to vary five or more orders of magnitude for the various POM compounds in sediments from different sources.[31] In general, the four- and five-ring POM are harder to transform than the two- and three-ring POM. Also sediments from pristine areas are not as active in transforming POM as those from previously contaminated streams. Contaminated streams have developed microbial populations capable of transforming POM.

The more volatile two- and three-ring POMs may evaporate from the surface of aqueous systems. The volatilization rate largely depends on the compound volatility and the turbulence at the air-water surface. The half-life (i.e., the time required to reduce the concentration present by a factor of one-half) for naphthalene (a two-ring POM) is around 10 hours at 25°C. The half-life for volatilization increases as the number of rings in the PAH increase, by roughly a factor of five per additional ring. These half-lives are for well-mixed waters. Stratification can deplete POM in the upper layers of the water and may result in longer half-lives under field conditions.

The following predictions were made for anthracene in a slow-moving, muddy pond about five meters deep. These conclusions are from Reference 27 and should be considered tentative subject to further work.

1. Adsorption to bottom sediment and photolysis by sunlight removes negligible amounts of POM in this environment. In less turbid, shallower waters these processes would be more important.

2. Microbial degradation in the sediment is responsible for about 80 percent of the POM degradation under the model assumptions. This contribution is very sensitive to the pond ecology. If water toxicity, excessive depth, or water treatment prevents microbial growth, then this main contributor to POM degradation will be absent.

3. Adsorption onto particulates and subsequent sedimentation may account for about 15 percent of the degradation.

4. Volatilization to the air is predicted to account for about 5 percent of the reduction seen from anthracene.

5. The half-life of anthracene in the water under these conditions is tentatively predicted to be about a day to a week. Again, this is almost entirely dependent on microbial degradation being present.

6. Half-lives for four- and five-ring POMs will be longer than for anthracene because both microbial degradation and volatilization are slower for the higher ring compounds.

EPA Athens Environmental Research Laboratory

SRI International under contract to EPA's Athens Environmental Research Laboratory has published their best current procedures for assessing the enviromental effects of a chemical in a freshwater aquatic system. The procedure includes measurement of the rates of degradation due to volatilization, oxidation, hydrolysis, photolysis, adsorption to sediments, and microbiological transformation. A computer model has been developed to use the rates of the individual reactions together with conditions representative of different aquatic systems (sediment content, biological activity, pH, etc.) to predict the environmental pathways of a chemical. Although some environmental pathways such as magnification in the food chain and biological transformation in the sediments are ignored in the model, it is felt that the procedure represents the state of the art of predicting pollutant behavior in freshwater systems. The following is a summary of two reports[37,38] which describe the procedure.

Because of an interest in pollutants likely to be generated by synthetic fuel plants, the AERL work used several POM compounds as illustrative compounds for their procedure: p-cresol, benz(a)anthracene, benz(a)pyrene, quinoline, benzo(f)quinoline, 9H-carbazole, 7H-dibenzo(c,g)carbazole, benzo(b)thiophene, and dibenzothiophene. The physical properties, chemical transformations and biodegradations of these compounds were measured. Benzo(a)pyrene is believed to be the most representative of these compounds for discussion of POMs generated by the ferroalloy industry. The laboratory studies which were made on benzo(a)pyrene indicate that by far the predominant removal mechanism is adsorption onto suspended and settled particles present in the water. The probable fate of the benzo(a)pyrene entering all but the very cleanest natural waters is rapid absorption onto suspended solids which will accumulate in the bottom sediments. In this work the biological cultures which were tested were found not to degrade benzo(a)pyrene, and no biodegradation is accounted for in the model. For a simple two-compartment pond consisting of a water phase and a sediment phase, the model predicted an overall half-life of 7.3 hours for benzo(a)pyrene and that 93 percent of the benzo(a)pyrene would be adsorbed onto the bottom sediments. For a more complex lake environment which includes effects due to changes in depth and distance from the pollutant source, a similar half-life was predicted with 71 percent of the B(a)P adsorbed onto the sediment.

Research Summary and Application to Ferroalloy Manufacture

As seen, several processes may be operating to transform POM compounds in freshwater systems. There is a disagreement between researchers for some of the major removal mechanisms, for example biodegradation. Therefore, predicting the combined effect of the removal mechanisms is risky at the current level of knowledge. However, some qualitative conclusions can be drawn although they should be interpreted under the following qualifications:

> All predictions are tentative. Well-controlled laboratory tests have been made on only a few POM compounds. Data needed for the modeling of aquatic systems are only now being generated. Field studies of the laboratory predictions have not yet been done.
>
> There are large uncertainties in many of the physical parameters needed in modeling studies (e.g., turbulence at the air-water interface, sediment loading, stratification).
>
> The models are very sensitive to factors that are site-specific, (e.g., depth, turbidity, water velocity, microbial activity).

The two-compartment pond model and the more complex model in the AERL work[37,38] might be considered as rough approximation to the processes that occur in wastewater treatment ponds in the ferroalloy industry. The waterflow, sediment concentrations, pond depths, pH, etc. used to characterize the model lakes and ponds are close to the characteristics of the wastewater ponds in the ferroalloy industry, but are not exactly the same. The following qualitative conclusions are drawn.

(1) The concentration of POM in the outfall from such a waste treatment pond will not be determined by solubility of POM in pure water since large quantities of solids are present in wastewaters from ferroalloy scrubbers. The POM concentration in the water phase instead will be determined by the distribution coefficient of the POMs between particulates and water. Hence, it is expected suspended solid in the outfall will be the main source of immediate POM discharges.

(2) Over 90 percent of the POM associated with the incoming wastewaters will be adsorbed onto the particulate present in the wastewaters. The models predicted desorption of benzo(a)pyrene which had been adsorbed onto bottom sediment resulting in maintenance of a very low concentration of benzo(a)pyrene in solution even after the pond has been abandoned. This long-term concentration was predicted to equal roughly the concentration in unpolluted groundwaters.

(3) Field data by Sahbad et al.[39] is cited as indicating an approximate half-life of five to ten years for benzo(a)pyrene which has accumulated in bottom sediments. Accordingly, large inventories of POM might be expected in

some solid waste sites and slurry ponds. The long-term mobility of POM is not known.

(4) Neither the potential effects of biomagnification in the food chain nor the rate of POM biodegradation in ferroalloy sediments are known. Both effects are critical in determining the lifetime and environmental impact of the inventory of POM.

9.3 POM BEHAVIOR IN AIR EMISSIONS

Sufficient information exists in the open literature on the possible effects of known carcinogens (benzo(a)pyrene, for example) that a discussion of the potential effects of their emissions from process stacks is not required. However, a discussion of potential reactions in the atmosphere is presented to illustrate the potential problems with emission of other compounds.

Both the low resolution mass spectrographic (LRMS) analysis and gas chromatography-mass spectrograph (GC-MS) analysis of samples collected in this study show that a number of fused ring hydrocarbons (polynuclear aromatic hydrocarbons, PNAs) probably remain in the furnace gases being emitted from control devices. Previous workers[40] have reported an apparent significant "excess carcinogenicity" (over that accounted for on the basis of B(a)P and other carcinogenic PAH) in urban air. In fact, studies of organic particulate collected in the Los Angeles basin have shown that this material is directly mutagenic[40] and does not require metabolic activation as does benzo(a)pyrene and other promutagens. Research work[40] has shown "that directly active mutagens, including nitro derivatives can form on exposure of PAH to gaseous pollutant." Perylene, a nonmutagen, for example was converted to a directly active mutagen by exposure to 1 ppm NO_2. Thus, it is important in assessing the pollution potential of ferroalloy emissions to consider not only the known carcinogens which are emitted but also to consider those compounds which can be converted to hazardous materials by exposure to environmental pollutants. Although the air near most ferroalloy plants may not contain the levels of NO_2 and HNO_3 used in the tests (comparable to Los Angeles basin concentration), the question of possible atmospheric reactions must be raised and considered in any future study.

9.4 POM DESTRUCTION

This and other studies cited show that ferroalloy furnaces do generate significant amounts of polycyclic organic matter, including polynuclear aromatics and known carcinogens. The study also provides strong evidence that the rate of generation of these compounds is considerably higher for covered (mix-sealed and sealed) furnaces than for the open furnaces. Since the reactions which occur deep in the furnace (reaction zone) should be affected little, if at all, by the type of furnace cover used, this difference must be accounted for primarily by the combustion of furnace gases in the open furnaces. Using data presented earlier in this section, we can estimate that the POM generation rate of open furnaces is less than 10 percent of the POM generation rate of a covered furnace (kg/Mw-hr basis). It is neither surprising that combustion destroys organics nor that some POM remains after combustion in an open furnace since these compounds have been found in other combustion products.

Open furnaces are used to produce most product lines. A prime advantage is easy access to the furnace to allow stoking which is necessary for some products. Covered furnaces, on the other hand, are used only for products that do not require stoking. The gas leaving an open furnace burns vigorously but the peak flame temperature is frequently moderated by the large volume of air which is drawn in to cool the gas. Low flame temperature and short residence time at these temperatures can lead to incomplete combustion of the more refractory organics. The most effective way to increase the flame temperature is to reduce the amount of air drawn into the furnace. This can be accomplished by tightly hooding the furnace, a method being more frequently used in the industry to reduce gas volumes to emission control devices. Hoods should extend to the top of the furnace and panels fit closely to prevent excessive air infiltration. Hood panels must be retractable to allow access for stoking. This would obviously create problems for retrofit situations because of increased structural support required. Also to be considered is modifications to duct work to withstand the higher temperatures. Gas cooling (radiant cooling sections or heat exchangers) would be required before the gas entered a baghouse. Although any heat recovered might be used in other areas of ferroalloy manufacture (conversion to steam or electricity to run pumps or fans, for example) the cost of this equipment may not be cost effective at this time.

There are several options, some of which are already in use by the industry, for handling POM generated by covered furnaces. Atmospheric emissions can be significantly reduced by using high energy scrubbers with efficient equipment for removing entrained water droplets and particulates. Provisions should be made to flare the cleaned gas 100 percent of the time or to use it as supplemental fuel in other plant processes. Since the use of scrubbers forces most of the organic into the scrubber water, provisions must be made to handle the slurry in an environmentally sound manner. The best technology in use to accomplish this uses solids removal (by clarification and vacuum filtration), recycling most of the water back to the scrubber, and treating the controlled blowdown by activated carbon adsorption for organic removal and chlorination for cyanide destruction. The activated carbon can be reactivated, used as fuel, or used as a reductant in the furnaces. The sludge should either be landfilled in an acceptable manner or possibly, pelletized for reuse in the furnace. Technology for the latter has not been demonstrated.

Other options involve burning the furnace gases before particulate capture occurs. This can be accomplished by providing for combustion under the furnace cover (see results for furnace A-1). Although this technique does result in significant reduction in organics, problems were noted with excessive fumes escaping the furnace cover of this furnace. Perhaps a well engineered design could eliminate this problem. This approach has the advantage that potential emissions to all three media could be significantly reduced by a single process change. Problems could arise, however, with furnace cover and ductwork cooling and, for retrofit application, pump and blower capacities would probably have to be increased. If the gas were cooled, the emissions could be controlled by a baghouse. Other techniques worthy of consideration are operating the furnace normally and ducting the dirty gas to a heat recovery type boiler (like a CO boiler in oil refining application) or converting the furnace to a tightly hooded open type furnace.

It is emphasized that burning the gas before removing the particulates is a preferable solution since it simultaneously reduces the organic pollutant load to all three media and that efficient high temperature combustion offers the best option for destruction of POMs and energy recovery. Any engineering solution will require extensive work beyond the scope of this report.

10. POLLUTION CONTROL ENERGY REQUIREMENTS

After the electric-arc furnaces themselves, the air pollution control equipment is by far the largest consumer of energy in ferroalloy manufacture. To remove particles from the furnace gases requires substantial fan horsepower. Hooding and gas movement required for control of other particulate sources such as tapping, crushing, screening, and secondary hooding over electrodes also is energy consuming. As an industry-wide average, gas cleaning uses energy equivalent to about 7 percent of the energy consumed by the furnaces.

Since most of the pollution control energy is expended on moving gas streams, the total energy requirement is best related to the gas volume collected multiplied by the pressure drop required by the control device. This energy is a function of alloy produced, the gas temperature, ductwork design, and the extent of combustion at the furnace surface. The amount of gas produced by the furnace is nearly proportional to the furnace energy consumption for a given product. The amount of entrained (combustion, cooling) air depends on furnace hood design.

The energy requirements for pollution control equipment were obtained from the literature and several manufacturers.

For control of furnace fumes the energy required varied from 0.01-0.12 kw for pollution control per kw furnace usage. There are two groupings of energy requirement: a cluster at about 0.02 kw per kw furnace usages for sealed furnaces and semi-sealed furnaces having no secondary hooding, and a second cluster at 0.06-0.10 kw per kw furnace usage for open furnaces. The energy requirements for the closed furnaces are lower because the exhaust gas flow rate is much lower (by as much as 1/50) since little air is entrained to burn the gases. However, semi-sealed furnaces which had secondary hoods to control fume leakage around the electrodes had energy requirements in the higher cluster. The advantage of lower furnace gas volume from semi-sealed furnaces is largely negated if secondary hooding is required.

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Control of taphole fumes is usually done by a separate hood with its own fan. For sealed and semi-sealed furnaces, a separate baghouse is normally used for cleaning taphole hood exhaust. The energy required is largely independent of furnace size and ranges between 150 to 300 kw. (For a 30 MW furnace this corresponds to 0.005-0.01 kw per kw furnace usage increment.)

The energy required for dust control from crushers, screens, etc., is dwarfed by the furnace control requirements. In a well-controlled plant, the energy required for such product handling control is 0.005 kw per kw furnace usage.

In control systems which use scrubbers, energy is associated with pumping water, etc. However, the energy expended in moving liquids is negligible compared to that required to handle furnace gas and fumes. A value of 0.001-0.003 kw per kw furnace usage is estimated for water pumping requirements.

The values given above for energy requirements are summarized in Table 19.

TABLE 19 . ENERGY REQUIREMENTS FOR POLLUTION CONTROL IN FERROALLOY MANUFACTURE

	Energy requirement, $\frac{\text{kw}}{\text{kw of furnace usage}}$	
Item	Open	Sealed
Breakdown by function		
Main furnace gases	0.04 - 0.11	0.01 - 0.03
Taphole control	0.005 - 001	0.005 - 0.01
Product handling	∿0.005	∿0.005
Pumps, etc.	Negligible	0.001 - 0.003
Model plants*	∿0.054	∿0.013
Industry wide average**		
1975	0.051	
1976	0.061	
1977	0.065	

*For 30 M furnace based on calculations in EPA-450/2-74-008. Numbers neglect product handling and are based on average gas flows with no provision for instantaneous fluctuations in furnace gas flows.

**Based on data in the Ferroalloys Association Statistical Yearbook 1977.[8]

11.0 SCREENING SAMPLES

In the initial phase of this project, RTI personnel inspected nine plants where ferroalloys are produced. These plants provide a good cross-section of the industry and included open, mix-sealed, and sealed submerged arc furnaces, and electrolytic manufacture of chromium and manganese. Emission control systems for tapping fumes, and primary and secondary furnace fumes were observed. The collection systems observed included baghouses, scrubbers, and an electrostatic precipitator.

During these visits a variety of samples were collected purely for preliminary screening purposes. All samples were of the "grab" type, and no compositing was done nor was any process-related information collected. Therefore, the samples must be considered as isolated, and possibly nonrepresentative of the operation. They do, however, provide useful information in that they give some indication as to which processes produce significant amounts of organic matter and the POM content of the sample. This information was considered when selecting plants for testing. It cannot be overemphasized that since the samples were isolated grab samples, no attempt should be made to use the data to calculate potential emissions from the source.

The information obtained is presented in Table 20. The first column gives the product type being made. All products except CaO and the electrolytic products were produced in submerged arc furnaces. Column 2 gives the source from which the sample was taken. The baghouse dust was typically taken from the load-out hopper. Scrubber discharge water samples were taken from local sumps at the furnaces. The vacuum filter solids were collected directly from the filter. The sampling method used does not allow for subtraction of any organic or suspended solid in the feed water. It also does not correct for the organic polymer added to the vacuum filter solids. Column 3 gives the type of furnace top cover in use. Close-hooded systems had doors extending from

TABLE 20. SCREENING SAMPLES

Furnace product	Sample source	Furnace type	Organics mg/kg Dry solids	Organics mg/L	POM, as approximate % organic found
Si	Baghouse	Open	266		1-3
Si	Baghouse	Open	224		
Si + 75% FeSi	Baghouse	Open	384		<0.1
L.C. SiMn	Baghouse	Open	65		
FeSi Sr.	Baghouse	Open	160		
50, 75% FeSi	Baghouse	Open	171		
50% FeSi	Baghouse	Close-hooded	312		
50% FeSi	Scrubber	Close-hooded	500	12	
50% FeSi	Scrubber	Mix-sealed	80,800	333	10-15
50% FeSi	Scrubber	Mix-sealed	41,100	86	25-50
75% FeSi	Scrubber	Mix-sealed	19,900	605	40-60
50% FeSI	Baghouse	Open furnace plus particulate from electrode area of mix-sealed furnace	1,100		1-3
50-75% FeSi	Baghouse	Secondary emissions from mix-sealed furnace	7,000		15-20
18% FeSi	Scrubber	Sealed	28,100	198	20-50

TABLE 20. (Continued)

Furnace product	Sample source	Furnace type	Organics mg/kg Dry solids	Organics mg/L	POM, as approximate % organic found
18% FeSi	Tar from 1st venturi	Sealed	16,700	1,980[a]	20-50
18% FeSi	Vacuum filter solids	Sealed	12,000	6,100[b]	40-60
FeCr	ESP	Open	163		1-10
FeCr	Tapping fume baghouse	Open	5,600		40-80
FeCr	Scrubber	Close-hooded	900		
SiMn	Scrubber	Open	4,900	12.9	2-4
SiMn	Tapping fume baghouse	Open	1,700		
H.C. FeMn	Scrubber	Open	10,000	12.2	<0.2
CaSiBa	Baghouse	Open	0		
CaC_2	Scrubber	Mix-sealed	22,300	8.33	
CaC_2	Secondary emissions	Mix-sealed	50		
CaO	Scrubber	Combustion gas was from mix-sealed furnaces	7,900	12.5	
SiMn, FeMn and Electrolytic Cr	Scrubber, feed to sludge beds	Open, mix-sealed, and electrolytic	19,100	10.4	1-3

TABLE 20. (Continued)

Furnace product	Sample source	Furnace type	Organics mg/kg Dry solids	Organics mg/L	POM, as approximate % organic found
Electrolytic Mn (Ore reduction area)	Baghouse	Electric induction	320		1-10
Electrolytic Mn (Mud to tailing pond)	Slurry		1,400	198	

a - mg/kg of solids as sampled (11.9% solids)
b - mg/kg of solids as sampled (50.77% solids)

the main hood to the top of the furnace. Column 4 gives the analytical results for GRAV (high boiling point) organics only. This is presented as mg of GRAV organics per kg of solids collected. For scrubber waters, the solids were filtered out (0.45 micron filters) and weighed and then both solids and liquids extracted for organics. Column 5 gives the actual concentration of GRAV organic in the water sample (including contribution from solids). The last column gives the approximate percentage of polycyclic organic material in the GRAV organic found. This was determined using a sensitized fluorescence technique.[41] The data indicate that the organic content of baghouse dust from open type furnaces is quite low (<500 mg/kg) and that the organic content of scrubber collected solids from open furnaces is somewhat higher (500-10,000 mg/kg solids in scrubber water), although the latter could be due to organics in the feed water. Tapping fumes from the open furnaces have organic contents of from 1,700 to 5,600 mg/kg solids. Organic content of solids from covered furnaces are much higher than from other type furnaces with a range of 12,000 to 80,800 mg/kg solids. The POM analysis indicates that particulates from open furnaces have quite low POM contents (0.1-10.0 percent of GRAV organic) while the POM is about 25-60 percent of the GRAV organic from covered furnaces. The data also suggest that the POM content of particulate in the gas escaping the furnace cover may be quite high.

Of particular interest was the implication from the data that there is not only a significant apparent difference in organic generation rates between open and covered furnaces, but there also appears to be a difference in the amount of organics generated by covered furnaces producing the same or different products. This observation was considered in the selection of furnaces for more detailed testing.

12.0 PLANT DESCRIPTIONS AND TEST RESULTS

IERL-RTP Level 1 testing was performed at three plants designated A, B, and C. Two furnaces were tested at each plant. In addition, the final wastewater discharge from each plant was sampled and analyzed.

The plants and furnaces were selected for testing based on several factors which included: manufacture of a major ferroalloy product, typical size furnaces, manufacture of the same product in different type furnaces or related products in the same type furnace. Known or suspected pollution potential of the plant was not a prime consideration.

This section of the report is divided into three major subsections, each dealing with a single plant. Each subsection contains a general plant description, a description of one furnace tested, the tests conducted on that furnace and the results obtained. The same information is then given for the second furnace tested.

At Plant A, a comparison was made of the production of high carbon ferromanganese (H.C. FeMn) produced in an open furnace and in a mix-sealed furnace using undercover combustion of process gas. At Plant B a comparison was made of open and mix-sealed furnaces producing 50 percent ferrosilicon (50 percent FeSi). The product is half iron and half silicon, the percent figure refers to the silicon content. At Plant C a comparison was made for production of 50 percent FeSi and 75 percent FeSi in mix-sealed furnaces.

12.1 PLANT A TESTS

Sampling at Plant A was conducted to compare pollutants from different furnaces producing high carbon ferromanganese. Furnace A-1 is a mix-sealed furnace that has been modified (holes cut in top cover) to allow air to be drawn into the furnace. The air drawn in allows virtually complete combustion of the furnace gases under the furnace cover (at least during the test period). Furnace A-2 is a typical open furnace design that allows combustion of the furnace gas as it leaves the furnace. The primary difference in these two modes of operation is that less air is drawn into furnace A-1, thus allowing the gases to burn at a higher temperature. Also the volume of gas treated by the pollution control equipment is substantially less for furnace A-1.

12.1.1 Plant A General Description

This ferroalloy facility is located near a river. The plant produces SiMn, FeMn, and FeCr in submerged arc furnaces. Refining of some ferroalloys and production of other material, e.g., Vanadium Carbide, is accomplished in the Simplex plant, a high temperature vacuum operation. High purity--99.8$^+$ percent--chromium is produced in an electrolytic shop.

Wet scrubbers (disintegrators and venturi types) are used to control emissions from the submerged arc processes. Tapping fumes on one furnace are controlled by a small baghouse. All process water from the electrolytic plant waste is collected and oxidized (by ozone) in a Unox® treatment system. The treated water is mixed with the furnace wastewater and then flows into one of several ponds occupying about 100 acres near the river. Once through cooling water and treated sanitary waters do not enter this system. The solids settle out and the clarified water overflows into the river. The settled solids in the pond are dredged out and pumped to a diked impoundment located behind the plant, well away from the river.

Table 21 lists the submerged arc furnaces, type, and design power rating for the products listed. Here, as in related descriptions of other plants, the furnace number designation is not the same as the furnace test number, i.e., A-1 is not furnace 1 of Table 21.

TABLE 21. SURMERGED-ARC FURNACES AT PLANT A

FCE No.	Type	Mw Rating, Approximate	Product
1	Open	30	SiMn
2	Semi-sealed	7.5	FeMn
3	Semi-sealed	7.5	FeMn
4	Semi-sealed	7.5	FeMn
5	Semi-sealed	12	FeCr
6	Semi-sealed	12	FeCr
7	Open	16	FeMn
8	Semi-sealed	7.5	FeMn
9	Semi-sealed	11.4	FeMn

Raw materials for the plant are loaded into weigh cars inside a covered building. The material is transported via skip hoists through a covered duct to feed bins above the furnaces. No significant amounts of particulate were observed in these areas.

Two of the furnaces not tested are described below.

Furnace No. 3 - Semi-sealed Producing H.C. FeMn and Operating at 7.9 MW.

Raw materials are fed onto the furnace cover and around the electrodes. Occasionally the material on the cover is pushed up to the electrode to feed into the furnace and to maintain the seal. There is a hood system above the cover which collects gas and particulate leakage and exhausts through a roof vent without passing through a collector. Fumes generated by this source were normally light with occasional episodes of moderate to heavy fumes.

The tapping area has a duct approximately 1 x 2 meters (3 feet by 5 feet) which collects fumes in the area and exhausts them through the roof directly to the atmosphere. Capture efficiency of the hoods during the tapping period was judged to be relatively poor. Tapping occurs about once every 2-2 1/2 hours and lasts about 15 minutes.

Gas from under the furnace cover is exhausted through two parallel Buffalo Forge scrubbers. Gas volume through each scrubber, a multistage centrifugal type, is about 56.6 m^3/min (2000 ACFM). Gas generated by the furnace reactions is about 36.8-40 m^3/min (13-1400 CFM). The carbon monoxide content of the scrubber discharge is less that 40 volume percent and varies somewhat with furnace operating conditions (air drawn in through the mix seals and other openings dilutes the gas and also burns some of the CO to CO_2; available oxygen in Mn ore oxidizes some CO to CO_2). Although the cleaned gas is routed to a flare stack, plant personnel report that it is difficult to keep the flare lit. Thus, the gases sometimes are not burned.

Furnace No 1 - Open Producing SiMn and Operating at 29 Mw

This furnace is equipped with a hood extending to within about 1.5 meters (5 feet) of the stoking deck floor. Chain curtains extend down from the hood to the floor. The chains can be pulled up to allow access for the stoking equipment. There was a well distributed flame across the furnace charge surface, indicating good combustion. Fume collection by the hood system was reasonably good although some fume was observed escaping the system and exiting through the roof monitor. Furnace gases collected pass through a twin Venturi scrubber which has two mist eliminators. The scrubber is equipped with two 1250 hp blowers and handles a total of 5660 m^3/min (2.5 cm Hg - 57°C) (1 inch H_2O, 135°F). The scrubber pressure drop is 141 cm Hg (55.57 inches of water) and has a reported dust collection efficiency of 99 percent. The scrubber sludge is collected in two small settling pits where some of the solids settle. The overflow from the pits goes to the fluid waste system and then to the settling beds. Tapping fumes from this furnace are collected and particulates removed by a cyclone and baghouse.

All of the slag from H.C. FeMn production is used as raw material for SiMn production. Slag from SiMn production is sold locally and is used as road construction material.

Medium carbon products are made by blowing oxygen through the molten alloy while it is in the ladle. The reaction was said to be quite exothermic. A 2832 m^3/min (100,000 CFM) fume collection system is used to control fumes generated during the oxygen blowing. RTI personnel did not observe this operation.

General Information

All of the semi-sealed furnaces at this plant (with the exception of Nos. 6 and 9 FCES) use pre-baked electrodes. Open furnaces (such as Nos. 1 and 7) use the self-baking type. Electrode consumption on the smaller furnaces is 15-17 kg/Mg (30-35 lbs/ton) of alloy produced. Electrode consumption for SiMn is about 25 kg/Mg (50 lbs/ton) of alloy produced.

Metal refining is performed in the Simplex plant. This is the largest ferroalloy vacuum refining operation in the world. The material to be refined is loaded into the vacuum chambers which are about 5 meters (15 feet) in diameter and 46 meters (150 feet) long. The material can then be heated to over 1090°C (2000°F) at pressures below 100 microns (<0.1 torr).

There are three electrolytic facilities at the plant that produces manganese metal and chrome metal. The only other operation of this type producing chromium metal is in Japan. The raw material (Hi carbon ferrochrome) which contains about 66 percent chromium is extracted with sulfuric acid and ammonia. Waste ferrous ammonium sulfate and waste electrolytic solution are neutralized and treated in the Unox® system. The small amount of waste lead sludge generated in the process from anode dissolution is presently being stored until a market is developed or a disposal method is found.

12.1.2 Furnace A-1 Description

Furnace A-1 (Figure 3), a mix-sealed furnace design, was modified by cutting holes in the furnace cover. This modification was made to relieve pressure during periods of sudden furnace blows. During normal operations, air is drawn into the furnace causing virtually complete combustion of the furnace gases before they exit the furnace. This is confirmed by an Orsat reading (Table 25) showing less than 1 percent CO in the effluent gas.

Three carbon electrodes, arranged in a delta formation, pass through the furnace cover and extend well into the furnace. Raw materials are blended in the mix house and stored in bins above the furnace. This material is fed into the furnace, as needed, through openings around the electrodes. Fumes, gases, and particulate escape from the furnace cover and are collected by a hood and exhausted, uncontrolled, directly to the atmosphere through stacks on the building roof. The opacity of these stacks is monitored (less than 1 Ringleman) and reported to regulatory authorities. The emissions from this area are substantially greater than is typical in the industry (based on visual comparisons by the test crew).

Gases and dust are withdrawn from the furnace and cooled by water sprays before passing through a high pressure drop Pease-Anthony venturi scrubber. After passing through a water knock out tank and the gas blower, the gases are exhausted to the atmosphere. Clarified river water is used in the quench sprays and the venturi. All condensed and collected scrubber water is collected in a common sump before entering the plant sewer system.

12.1.3 Test Description, Furnace A-1

Samples were taken (see Figure 3 for sampling points) of the cleaned gases from the primary emission control system, and of the scrubber feed and discharge water. The sampling point for the gas sample was in a 50.8 cm (20 inch) internal diameter duct about 3 meters (10 feet) downstream of the blower and about 1 meter (3 feet) upstream of the gas flow measuring orifice (a velocity traverse of the duct, demonstrated that the orifice had no effect

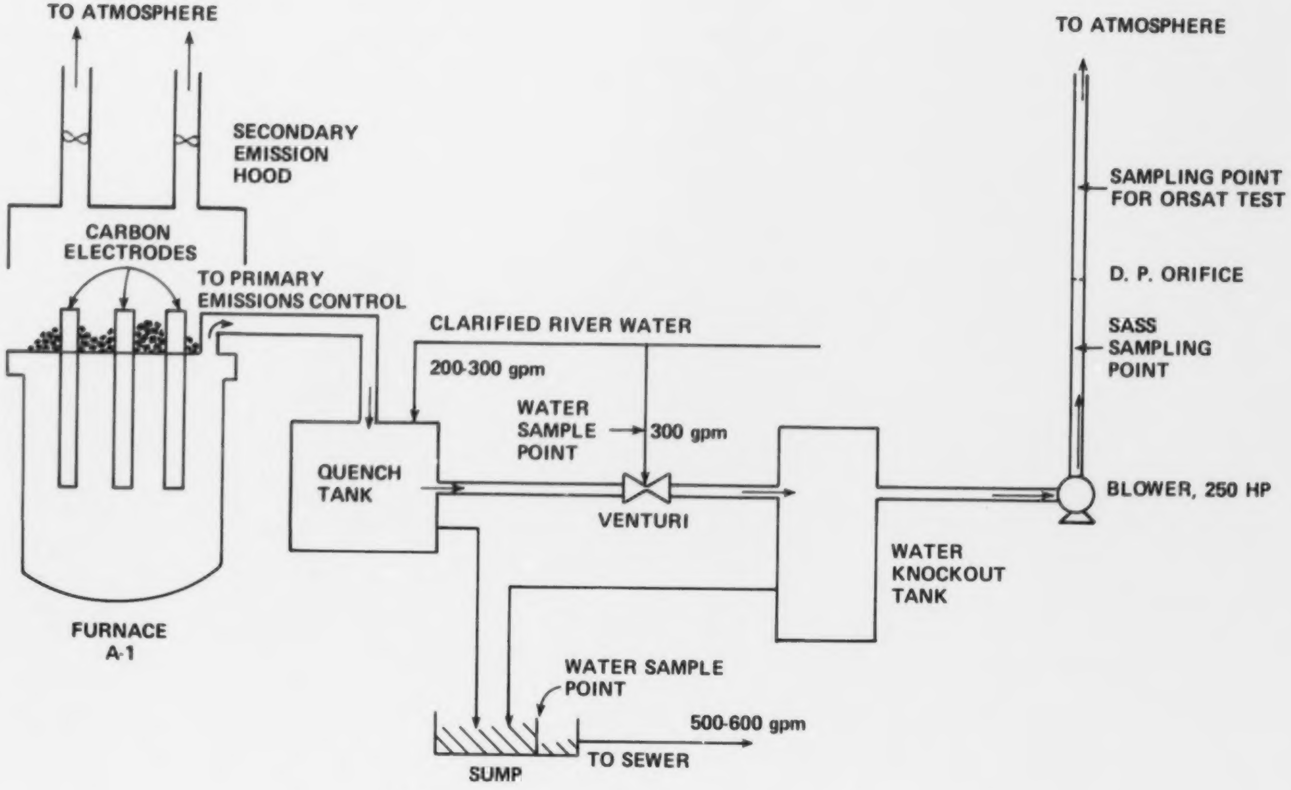
TO ATMOSPHERE
SECONDARY EMISSION HOOD
CARBON ELECTRODES
TO PRIMARY EMISSIONS CONTROL
FURNACE A-1
QUENCH TANK
CLARIFIED RIVER WATER
200-300 gpm
WATER SAMPLE POINT
300 gpm
VENTURI
WATER KNOCKOUT TANK
WATER SAMPLE POINT
500-600 gpm
TO SEWER
SUMP
TO ATMOSPHERE
SAMPLING POINT FOR ORSAT TEST
D. P. ORIFICE
SASS SAMPLING POINT
BLOWER, 250 HP

Figure 3. Emission control system on furnace A-1.

on the flow profile). The sample was collected using the Source Assessment Sampling System (SASS). A two-liter sample of the scrubber feed water was collected from a tap near the venturi and a two-liter sample of the scrubber discharge water was collected at the sump overflow weir thirty minutes after SASS sampling began. The test was terminated before additional samples could be taken because of a malfunction in the furnace electrode positioning equipment which required a furnace shutdown.

Since raw materials are fed to the furnace from storage bins, an "instantaneous" feed rate cannot be determined. Therefore, the feed rate was determined by counting the number of "trips" made by the preweighed cars to the storage bins in a 24 hour period when the furnace was operating at 11.8 MW (normal power level). A typical alloy analysis from furnace A-1 is presented in Table 22. In Table 23 details of the mix fed to the furnace are given. In Table 24 the analysis of the raw materials used in both furnaces A-1 and A-2 is given. Operating at 11.8 MW furnace A-1 produces 4654 kg (10,261 lbs) of HC FeMn alloy and 2909 kg (6413 lbs) of slag per hour (specific energy consumption 2.53 kwh/kg--5.58 kwh/lb--alloy; 0.625 kg slag/kg alloy).

TABLE 22. FURNACE A-1 ALLOY ANALYSIS

Component	Percent by Weight
Mn	80.00
Fe	11.80
Si	0.50
Cr	0.15
P	0.17
As	0.12
C	6.80

During the test period the furnace was operating at 11.4 MW. The pressure under the furnace cover was -0.011 cm of Hg (-0.06 inches of water) and the gas temperature at the furnace exit was 482-538°C (900-1000°F). The venturi was operating with a pressure drop of 13.6 cm of Hg (73 inches of

TABLE 23. RAW FEED FOR FURNACE A-1 AS GIVEN BY THE PLANT

At 11.8 MW OPERATION (4.65 Mg ALLOY/HR)

Component	Source Pile No.	Kg per Trip	Kg per Hour	Kg per Mw-Hr	Kg consumed Per Mg Alloy Produced	Kg consumed Per Mg of (Alloy + Slag)
Reducing Agent						
Buckwheat Coke	522	826	2511	213	5408	332
Recycled Materials						
Std FeMn Fines	912	136	489	35	89	55
Std FeMn Slag	369	136	489	35	89	55
H/H Spills (Conglomerate of Ore and Reducing Agent)	-	23	69	5.9	15	9
Mn Ores						
50% Associated	113	454	1380	117	296	182
Wessels	129	295	897	76	192	118
Amapa Pellets	137	953	2898	245	622	383
Comilog	138	1179	3587	304	770	474
Russian	123	227	690	58.5	148	91
Mor Pellets	258	159	483	41	104	64
Electrodes	-	-	67.6	5.9	15	9
Total		4386	13410	1374	2881	1773

TABLE 24. MANGANESE ORE ANALYSIS*, FURNACES A-1 AND A-2

		Percent by Weight													
Component	Pile No.	Book H_2O	Book Mn	Fe	P	SiO_2	AL_2O_3	CaO	BaO	K_2O	CO_2	O_2	TiO_2	As	MgO
Associated 50%	113	1.51	53.27	9.10	0.033	4.22	0.31	2.03	0.80	0.12	0.96	7.27	0.04	0.002	0.45
Russian	123	8.54	47.13	1.33	0.161	9.94	1.71	1.19	1.17	0.40	0.85	10.06	-	-	1.40
Wessels	129	1.46	47.09	12.74	0.032	5.04	0.38	4.12	0.35	0.10	2.21	6.09		0.002	0.72
Amapa Pellets	137	1.68	54.34	6.82	0.082	5.89	6.97	0.35	0.23	0.76	0.03	4.65	0.47	0.10	0.10
Comilog	138	8.31	51.88	2.54	0.112	2.51	6.07	0.05	0.24	0.63	0.06	14.31	0.24	-	0.06
Amapa-GSA-LG	140	5.78	49.74	5.55	0.93	3.11	5.20	0.09	0.20	1.85	-	13.43	0.36	0.165	0.06
Amapa Ore	186	4.78	48.54	5.57	0.086	2.89	5.28	0.07	0.19	1.44	-	13.09	0.38	-	0.05
Mor Pellets	258	4.0	65.26	4.58	0.075	0.48	0.055	0.42	-	-	-	4.00	-	-	0.61
Angolan	5105	6.80	47.86	2.75	0.068	6.95	2.67	0.78	5.71	1.10	0.09	10.78	-	-	0.47

*As given by plant personnel.

water). Total water flow to the quench and venturi was 1.9-2.3 m^3/min (500-600 gpm).

Chemicals were added to the SASS system at a remote location to avoid contamination at the work site. After verifying that the furnace was operating properly, the probe was inserted into the duct and sampling started. Approximately one hour later preparations for a furnace shutdown began because of a malfunction in an electrode positioner. The furnace was not scheduled for a restart in less than eight hours. Since sufficient sample had been collected the samples were recovered for analysis.

12.1.4 Test Results, Furnace A-1

On-Site Results

A velocity traverse of the exhaust duct at the SASS sampling point gave the following results:

ΔP Maximum	-	0.45 cm Hg (2.4 in H_2O)	
ΔP Minimum	-	0.37 cm Hg (2.0 in H_2O)	
ΔP Average	-	0.406 cm Hg (2.174 in H_2O)	
Duct Temperature		52.2°C	(126°F)
Duct Area		0.203 m^2	(2.18 ft^2)
Moisture		12 percent	
Gas Velocity		1573 m/min	(5160 ft/min)
Flow Rate, Actual		318.6 m^3/min	(11252 ft^3/min)
Flow Rate, Standard Conditions		255.1 m^3/min	(9010 ft^3/min)

The results of an Orsat analysis of a gas sample taken near the SASS sample point is shown in Table 25. Data taken with the SASS train during the actual test is given in Table 26.

Particulate

The particulate generated, captured by the scrubber, and emitted to the atmosphere by furnace A-1 is presented in Table 27. It should be noted that these data apply only to particulate in the primary control system. A substantial amount of fumes escaped through the furnace cover and were removed by the secondary control system. These secondary emissions are exhausted uncontrolled, directly to the atmosphere. No particulate was captured by the cyclones (1 micron and greater) indicating that most, if not all, of the particulate passing through the scrubber is submicron in size. Particulate

TABLE 25. ORSAT ANALYSIS, FURNACE A-1

Component	Percent by Volume
CO	0.60
CO_2	16.7
O_2	11.8
H_2	0.4
Inerts (N_2)	70.5

TABLE 26. SASS TEST DATA, FURNACE A-1

Date of Test	4/4/79	
Volume of Gas Sampled	5.082 Nm^{3*}(179.446 DSCF*)	
Stack Gas, Temperature	52.2°C	(126°F)
Pressure	76.43 cm Hg	(30.09 in Hg)
Dry Molecular Weight	31.03	
Wet Molecular Weight	29.52	
Moisture, Percent	11.6	
Velocity	26.2 m/sec	(86 ft/sec)
Flow Rate	255.1 Nm^3/min (9010 DSCFM)	
	318.6 Am^3/min** (11252 ACFM)	
Total Sampling Time	67.5 minutes	
SASS Flow Rate	0.0753 Nm^3/min (2.66 DSCFM)	
Percent Isokinetic	87.5	

---

*20°C (68°F), 76.0 cm Hg (29.92 in Hg), moisture-free basis.
**Actual (at stack conditions) flow rate.

TABLE 27. PARTICULATES, FURNACE A-1[a]

Air Emissions

Sample Point - In duct downstream of scrubber.

Volume of Gas Sampled: 5.082 NM^3

Sample Type	Weight Collected, mg	Concentration mg/NM^3	Kg Emitted per Hour	Kg Emitted per MW-hr	Kg Emitted per Mg Alloy
Probe	48.3	9.50	0.146	0.0128	0.031
1μ Filter	205.2	40.38	0.618	0.054	0.13
1-10μ Cyclones	0	0	0	0	0
Total	253.5	49.88	0.764	0.067	0.16

Particulate removed by the scrubber

Sample Point - At scrubber discharge sump weir and at inlet to scrubber venturi.

Sample Type	Weight Solids Collected, mg	Concentration mg/L	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Scrubber Inlet	128	64.7	7.3	0.64	1.57
Scrubber Discharge	931	474.5	53.9	4.73	11.55
Net Scrubber Solids		409.8	46.5	4.10	9.98
Total Solids going to the Primary Control System*			47.3	4.1	10.14
% Scrubber Efficiency, Solids			98.4		

*Substantial emissions observed from secondary emission control system.

[a] In this and all similar tables, totals may differ from the sum of individual values due to rounding errors.

concentration in the scrubbed gas was 49.88 mg/Nm^3 or 0.764 kg/hr emitted to the atmosphere. The gas scrubber captured 46.5 kg/hr of particulate matter or 98.4 percent of the dust collected by the primary control system. Total particulate concentration before the scrubber was, therefore, 3090 mg/Nm^3. Particulate emitted to the atmosphere from the primary control system is 0.067 kg/Mw-hr, substantially below the 0.23 kg/Mw-hr NSPS limitation. The NSPS limits pertain to total emissions, however, and it is expected that inclusion of secondary emissions would substantially raise the furnace emission factor.

Organic

Given in Table 28 are the amounts of organic generated, captured by the scrubber, and emitted to the atmosphere from furnace A-1. The concentration of organic matter in the scrubbed gas (exhausted to the atmosphere) was 20.0 mg/Nm^3 or 0.31 kg/hr which is about 40 percent as great as the particulate emissions. The scrubber captured an additional 0.41 kg/hr. Thus, the total organic matter entering the scrubber was 46.8 mg/Nm^3 or 0.72 kg/hr (0.0628 kg/Mw-hr). The scrubber efficiency of 57.2 percent for the capture of organics is substantially less than that for particulates (98.4 percent).

Level 1 Organic Analysis

The SASS train catch was analyzed for organic compound categorization as follows. The particulate catches were separately extracted with methylene chloride and a TCO and GRAV determined. The extracts were then combined and fractionated by liquid chromatography (LC) and each fraction analyzed for total chromatographical organics (TCO)--low boiling point material--and GRAV--high boiling point material. The infrared spectrum of each fraction was also determined. A low resolution mass spectrograph (LRMS) analysis was done on LC fractions 2 and 3 combined. A similar analysis scheme was followed for the SASS organic module and condensate (both combined).

Aqueous samples (scrubber feed and discharge water) were filtered to determine suspended solids concentration and the solids and aqueous phases separately extracted with methylene chloride. A TCO and GRAV was determined

TABLE 28. ORGANICS, FURNACE A-1

Air Emissions

Sample Point - In duct downstream of scrubber.

Volume of Gas Sampled: 5.082 M^3

Sample Type	Weight Collected, mg	Concentration mg/NM^3	Kg Emitted per Hour	Kg Emitted per MW-hr	Kg Emitted per Mg Alloy
Probe & Filter	9.0	1.8	0.027	0.0024	0.0058
Organic Module	92.8	18.3	0.28	0.025	0.060
Total	101.8	20.0	0.31	0.027	0.066

Organic Removed by the Scrubber

Sample Point - At inlet to scrubber and at scrubber discharge sump weir.

Sample Type	Weight Solids Collected, mg	Concentration mg/L	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Scrubber Inlet	15	7.6[a]	0.86	0.076	0.19
Scrubber Discharge	22	11.2[b]	1.27	0.11	0.27
Net Organics Captured		3.6	0.41	0.036	0.088
Total Organics going to the Primary Control System			0.72	0.063	0.15
% Scrubber Efficiency, Organics			57.2		

[a] 57 Percent of Organic adsorbed on solids.

[b] 8.2 Percent of organics adsorbed on solids.

on each extract, the extracts for each sample combined and concentrated and the scrubber discharge water only was analyzed by LC, IR, TCO, GRAV, and LRMS as above. The LC, IR, and LRMS data are contained in the appendices.

In Tables 29 and 30 the data obtained is summarized. Of the organic matter captured by the SASS train 91.2 percent was found in the organic module (A1-X) with the remainder in the probe and filter (particulate catch). All of the organic found in the particulate catch was GRAV (high boiling point) material. GRAV material also accounted for 68.8 percent of the total organic captured by the SASS train. IR and LRMS spectra indicate the material is predominately high molecular weight aliphatics. No evidence was found for potential carcinogens.

The data for the organics found in the scrubber water is summarized in Table 30 (detailed analysis was not performed on feed water and thus was not subtracted). All of the organic found in the scrubber water was GRAV material. Significantly, this material was found to contain almost 1 mg/L of fused aromatics with molecular weights above 216. The LRMS indicates possible carcinogens at masses 228, 252, 256, and 302 (benzoanthracene, benzo(a)pyrene, dimethyl benzoanthracene, and dibenzochrysene isomer, respectively).

The above data indicate little organic matter is emitted from the furnace's primary gas system and that the scrubber effectively captures the polycyclic aromatic compounds.

12.1.5 Furnace A-2 Description

Furnace A-2 is a companion to furnace A-1 both in size and product (H.C. FeMn). The basic difference in the furnaces is that whereas A-1 is a covered furnace with undercover combustion, A-2 is an open design furnace with combustion at the furnace surface.

In this type furnace there is no top cover. Three 1.5 meter (60 inch) diameter carbon electrodes extend into the furnace. Blended raw materials from storage bins above the furnace are fed into the furnace so that it is always full. Since there is no furnace cover, gases from the furnace mix with air (drawn in by the hood system) and burn vigorously at the furnace surface. The hood, which is about 3-4 meters (9-12 feet) above the furnace surface, draws in a considerable amount of air while capturing the gas and fumes coming from the furnace. The collected gases and fumes are then drawn through a twin

TABLE 29. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. A1-X

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/m^3	2.0	1.0	7.8	3.1	1.7	2.0	1.3	19.0
TCO, mg/m^3	1.85	0.55	0.47	1.54	0.79	0.35	0	5.66
GRAV, mg/m^3	0.15	0.45	7.33	1.56	0.91	1.65	1.3	13.44

Category	Assigned Intensity - $mg/(m^3)$							
Aliphatic Hydrocarbons	QNS[*]	-	100/7.8	QNS[*]	QNS[*]	-	-	7.8
Halogenated Aliphatics	-	10/0.25[†]				-	-	0.25
Aromatic Hydrocarbons		10/0.25				-	-	0.25
Halogenated Aromatics		10/0.25				-	-	0.25
Silicones		10/0.25				-	-	0.25
Heterocyclic O Compounds		-				-	-	
Nitroaromatics		-				-	-	
Ethers		-				-	-	
Aldehydes		-				-	-	
Phosphates		-				100/0.51	10/0.03	0.54
Nitriles		-				-	-	
Heterocyclic N Compounds		-				10/0.05	10/0.03	0.08
Heterocyclic S Compounds		-				-	-	
Alcohols		-				10/0.05	10/0.03	0.08
Phenols		-				10/0.05	10/0.03	0.08
Ketones		-				100/0.51	100/0.33	0.84

(Continued)

[*] Quantity Not Sufficient.

[†] The data are presented as assigned intensity (from IR and/or LRMS)/concentration in this and all similar tables.

TABLE 29. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. A1-X (Cont'd)

Category	Assigned Intensity - mg/(m^3)							
Amines	QNS*	-	QNS*	QNS*	QNS*	10/0.05	10/0.03	0.08
Alkyl S Compounds		-				10/0.05	10/0.03	0.08
Sulfuric Acids		-				10/0.05	10/0.03	0.08
Sulfoxides						10/0.05	10/0.03	0.08
Amides						10/0.05	10/0.03	0.08
Carboxylic Acids						10/0.05	10/0.03	0.08
Esters						100/0.51	100/0.33	0.84

*Quantity Not Sufficient.

TABLE 30. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. A1-SWD

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/L	0.15	0.15	0.9	0.9	0.45	1.3	0.6	4.45
TCO, mg/L	0	0	0	0	0	0	0	0
GRAV, mg/L	0.15	0.15	0.9	0.9	0.45	1.3	0.6	4.45

Category	Assigned Intensity - mg/L							
Aliphatic Hydrocarbons	QNS*			QNS*	-	-	QNS*	
Halogenated Aliphatics					-	-		
Aromatic Hydrocarbons		100/0.15	100/0.81		-	-		0.96
Halogenated Aromatics					-	-		
Silicones					-	-		
Heterocyclic O Compounds					-	-		
Nitroaromatics					10/0.01	-		0.01
Ethers					100/0.1	-		0.1
Aldehydes					10/0.01	-		0.01
Phosphates					100/0.1	10/0.04		0.14
Nitriles					10/0.01	-		0.01
Heterocyclic N Compounds					10/0.01	10/0.04		0.05
Heterocyclic S Compounds					10/0.01	-		0.01
Alcohols					10/0.01	10/0.04		0.05
Phenols					10/0.01	10/0.04		0.05
Ketones					100/0.1	100/0.4		0.5

(Continued)

*Quantity Not Sufficient.

TABLE 30. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. A1-SWD (Cont'd)

Category	Assigned Intensity - mg/L							
Amines	QNS*	QNS*		QNS*	10/0.01	10/0.04	QNS*	0.05
Alkyl S Compounds					10/0.01	10/0.04		0.05
Sulfuric Acids					10/0.01	10/0.04		0.05
Sulfoxides					10/0.01	10/0.04		0.05
Amides					10/0.01	10/0.04		0.05
Carboxylic Acids					10/0.01	10/0.04		0.05
Esters			0.09		10/0.01	100/0.4		0.50

*Quantity Not Sufficient.

venturi flooded disc type scrubber, Figure 4, mist eliminators and exhausted by two 1250 hp fans through a 2.44 meters (8 feet) diameter, 38.1 meters (125 feet) tall stack.

A major difference in the emission control system, as compared to furnace A-1, is that the hood system collects all furnace gas and fumes. The A-1 furnace has two emission control systems, primary and secondary (for collection of furnace cover fumes). The data comparison, see 12.1.9, indicates that a substantial fraction of the fume generated by furnace A-1 escaped into the secondary collection system.

12.1.6 Test Description, Furnace A-2

Samples were taken (see Figure 4 for sampling points) of the cleaned gas and of the scrubber discharge water. Since the same service water is used for all scrubbers, the feed water analysis for furnace A-1 was used. The sample point for the gas sample was about midway up the scrubber discharge stack. A velocity traverse showed an even flow profile. The sample was collected using the SASS system (the 10μ cyclone was not used due to a serious leak). A four-liter water sample was collected from the discharge of each mist eliminator (scrubber discharge point-1 liter of each collected every 30 minutes during the test). The test was stopped after 85 minutes when the furnace was shut down because of a problem at the power station.

Raw material feed rate was determined by counting "trips" by the preweighed feed cars in a twenty-four hour period of normal operation at 14.8 Mw. Details of the mix fed to the furnace are given in Table 31, and Table 24 gives the raw material analysis (supplied by the company).

Operating at 14.8 Mw, furnace A-2 produces 6,278 kg (13,840 lbs) of H.C. FeMn alloy and 3,924 kg (8,650 lbs) of slag per hour. The alloy analysis is similar to that given in Table 22.

During the test period the furnace was operating at 15.8 Mw. The gas temperature in the duct leading from the hood to the scrubbers was 93-116°C (200-240°F) at the point it leaves the furnace building. Significantly higher temperatures 204-538°C (400-1000°F) are occasionally measured at this point during furnace "blows" - periods when bridges of fused material suddenly collapse into the furnace and release gases trapped in the furnace. Furnace "blows" are extremely dangerous since the rapidly escaping gas can eject raw

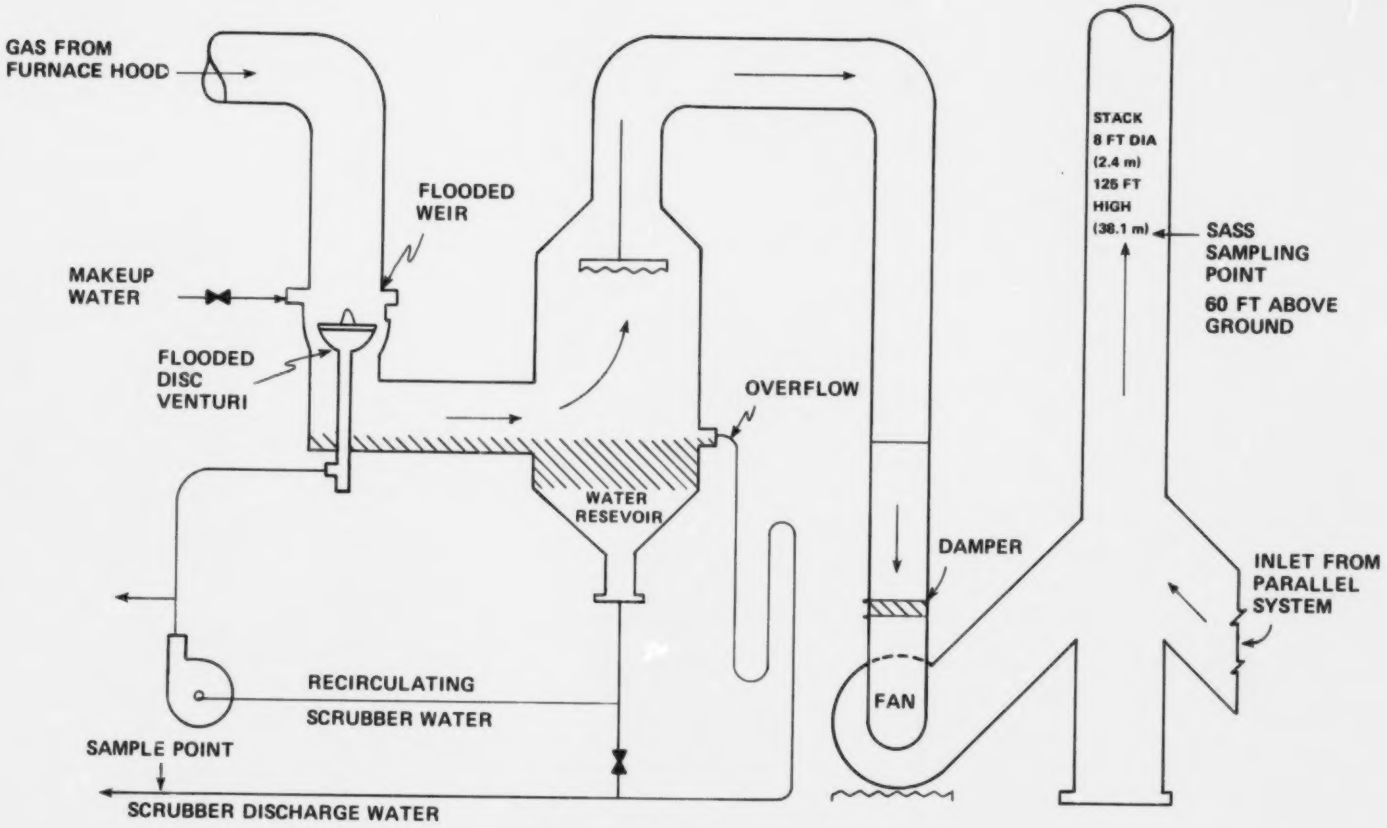
GAS FROM FURNACE HOOD
FLOODED WEIR
MAKEUP WATER
FLOODED DISC VENTURI
WATER RESEVOIR
OVERFLOW
RECIRCULATING SCRUBBER WATER
SAMPLE POINT
SCRUBBER DISCHARGE WATER
DAMPER
FAN
STACK 8 FT DIA (2.4 m) 125 FT HIGH (38.1 m)
SASS SAMPLING POINT
60 FT ABOVE GROUND
INLET FROM PARALLEL SYSTEM

Figure 4. Furnace A-2 emission control system.

TABLE 31. RAW FEED FOR FURNACE A-2 AS GIVEN BY THE COMPANY

14.8 Mw (6.28 Mg - ALLOY/hr)

Component	Source Pile No.	Kg per Trip	Kg per Hour	Kg per MW-Hr	Kg consumed Per Mg Alloy Produced	Kg consumed Per Mg of (Alloy + Slag)
Reducing Agent						
Buckwheat Coke	522	748	2,807	190	448	271
Recycle Materials						
Std FeMn Fines	912	136	510	34	82	50
Std FeMn Slag	369	272	1,021	69	162	98
Mill Scale	237	45	170	11	27	16
Mn Ores						
Angolan	5,105	318	1,191	80	190	115
Indian	141	227	850	58	136	82
Amapa	186	1,814	6,804	460	1,085	658
GSA Amapa	140	590	2,211	149	352	214
Mor Pellets	258	272	1,021	69	162	98
Electrodes	-	-	101	7	16	10
Total			16,685	1,127	2,660	1,612

material and molten metal. Each venturi scrubber was operating at a pressure drop of 8.7 cm Hg (46.5 inches of H_2O). Each of the two 1250 horsepower exhaust fans were operating at about 68 percent of maximum (~850 hp). Total scrubber discharge flow rate was estimated by plant personnel to be about 2.3 m^3/min (600 gpm).

After verifying that the furnace was operating normally, the SASS probe was inserted into the stack and sampling begun. One hour and 15 minutes later the sampling crew was advised that the furnace was to be shut down because of a problem at the power house. Since plant personnel could provide no estimate of the outage time, the test was stopped and the samples recovered.

12.1.7 Test Results, Furnace A-2

A velocity traverse of the exhaust stack was performed just prior to the SASS test and the following results were obtained:

ΔP Maximum	0.12 cm Hg	(0.65 inches H_2O)
ΔP Minimum	0.093 cm Hg	(0.50 inches H_2O)
ΔP Average	0.107 cm Hg	(0.574 inches H_2O)
Stack Temperature	32°C	(90°F)
Stack Area	4.67 m^2	(50.3 ft^2)
Moisture	7 percent	
Gas Velocity	788.2 m/min	(2,586 ft/min)
Flow Rate, Actual	3,676.6 m^3/min	(129,837 ft^3/min)
Flow Rate, Standard Conditions	3,196.4 m^3/min	(112,879 ft^3/min)

Data taken with the SASS train during the actual test is given in Table 32.

TABLE 32. SASS TEST DATA, FURNACE A-2

Date of Test	4/5/79	
Volume of Gas Sampled	8.2687 Nm^3	(292.005 DSCF)*
Stack Gas, Temperature	32°C	(90°F)
Stack Gas, pressure	75.44 cm Hg	(29.7 inches Hg)

(Continued)

Table 32 (Continued)

Dry Molecular Weight	29.1
Wet Molecular Weight	28.31
Moisture	7 percent
Velocity	13.53 m/sec (44.4 ft/sec)
Flow Rate, Actual	3791.7 A m^3/min (133,902 ACFM)
Flow Rate, Standard Condition	3355.4 Nm^3/min (118,495 DSCFM)
Total Sampling Time	82.7 minutes
SASS Flow Rate	0.1 Nm^3/min 3.53 DSCFM
Percent Isokinetic	117

*20°C (68°F), 76.0 cm Hg (29.92 inches Hg)

Particulate

In Table 33, the amounts of particulate generated, captured by the scrubber, and emitted to the atmosphere from furnace A-2 are given. In contrast to furnace A-1, these data apply to all particulate generated by the furnace (not including tapping, etc.) since a furnace cover, requiring a primary and secondary control system, is not used.

No particulate was captured by the cyclones (1 micron and greater) indicating that most, if not all of the particulate passing through the scrubber was submicron in size. Particulate concentration in the scrubbed gas was 27.7 mg/m^3 or 5.32 kg emitted per hour to the atmosphere. The gas scrubber captured an additional 169.6 kg/hr of particulate matter or 96.96 percent of the dust generated by the furnace. Particulate concentration in the gas stream before the scrubber was, therefore, 911.9 mg/m^3. Particulate emitted to the atmosphere is 0.337 kg/Mw-hr or 46.5 percent greater than would be allowed by NSPS of 0.23 kg/Mw-hr.

Organic

Given in Table 34 are details of the organics generated, captured by the scrubber, and emitted to the atmosphere from furnace A-2. The concentration of organic matter in the scrubbed gas (atmospheric emission) was 23.98 mg/m^3 or 4.6 kg/hr which is 86.5 percent as great as the particulate emission. The

TABLE 33. PARTICULATES, FURNACE A-2

Air Emissions

Sample Point - In discharge stack after scrubber.

Volume of Gas Sampled: 8.2686 NM^3

Sample Type	Weight Collected, mg	Concentration mg/NM^3	Kg Emitted per Hour	Kg Emitted per MW-hr	Kg Emitted per Mg Alloy
Probe	29.9	3.62	0.694	0.0439	0.10
1µ Filters	199.4	24.12	4.63	0.293	0.69
Cyclones	0	0	0	0	0
Total	229.3	27.73	5.32	0.337	0.79

Particulate Removed by the Scrubber

Sample Point - Discharge pipes on East and West scrubbers, and service water line.

Sample Type	Weight Solids Collected, mg	Concentration mg/L	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Service Water	128	64.7	8.8	0.56	1.31
Scrubber Discharge	10,140	1309.2	178.4	11.29	26.52
Net Scrubber Solids		1244.5	169.6	10.73	25.21
Total Solids			174.9	11.07	26.0
% Scrubber Efficiency, Solids			96.96		

TABLE 34. ORGANICS, FURNACE A-2

Air Emissions

Sample Point - In discharge stack after scrubber.

Volume of Gas Sampled: 8.2686 NM^3

Sample Type	Weight Collected, mg	Concentration mg/NM^3	Kg Emitted per Hour	Kg Emitted per MW-hr	Kg Emitted per Mg Alloy
Probe and Filter	15.2	1.84	0.35	0.022	0.05
Organic Module	183.1	22.14	4.25	0.27	0.63
Total	198.3	23.98	4.60	0.29	0.68

Organic Captured by the Scrubber

Sample Point - Discharge pipes on East and West scrubbers and service water line.

Sample Type	Weight Solids Collected, mg	Concentration mg/L	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Scrubber Inlet	15	7.6[a]	1.04	0.066	0.15
Scrubber Discharge	70.0	14.1[b]	1.92	0.12	0.29
Net Organics Captured		6.5	0.89	0.056	0.13
Total Organics			5.49	0.35	0.82
% Scrubber Efficiency, Organics			16.15		

[a] 57 Percent of organic adsorbed on solids.

[b] 44 Percent of organic adsorbed on solids.

scrubber captured an additional 0.89 kg per hour. Thus, the total organic matter entering the scrubber was 28.6 mg/Nm^3 or 5.49 kg/hr (0.35 kg/Mw-hr). The scrubber efficiency of 16.15 percent for organics removal is substantially less than the 96.96 percent found for particulate capture.

Level 1 Organic Analysis

The SASS train catch was analyzed for organic compound categorization as follows: the particulate catches were separately extracted with methylene chloride and TCOs and GRAVs determined. These extracts were then combined and fractionated by LC. An IR, TCO, and GRAV were run on each fraction. An LRMS was run on LC fractions 2 and 3 (combined). A similar scheme was followed for the SASS organic module and condensate (combined before extraction). The scrubber discharge water was filtered to determine suspended solids concentration and the solids and aqueous phases separately extracted. A TCO and GRAV was determined on each extract, the extracts combined and concentrated before analysis by LC as above. The LC, IR, and LRMS data are contained in the appendices.

In Tables 35 and 36 the data obtained are summarized. Of the organic matter captured by the SASS train 92.3 percent was found in the organic module (A2-X) with the remainder in the probe and filter (particulate catch). The organic found in the particulate catch was 98.7 percent GRAV material. GRAV material also accounted for 83.7 percent of the total organic captured by the SASS train. A large fraction of this material is in LC fraction 2 which is consistent with the compound categorization which shows predominant categories of aliphatic and aromatic hydrocarbons. The LRMS spectra of LC fractions 2 and 3 (combined) contains (among other masses) a major peak at M/e of 302 (possibly dibenzochrysene isomer) and a minor peak at M/e 276 (possibly indeno-(1,2,3-cd)pyrene) both known carcinogens.

The data for the organics found in the scrubber discharge water are summarized in Table 36. The total organic found was 98.6 percent GRAV material and was predominately normal and halogenated aliphatic and aromatic hydrocarbons. LRMS indicates the material is predominately (>80 percent) fused aromatic compounds with molecular weights above 216. High intensity peaks in the LRMS were found at M/es of 228, 252, 266, 276, 278, and 302 which indicates the presence of known carcinogens benzoanthracene (or chrysene),

TABLE 35. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. A2-X

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/m^3	1.0	5.7	0.9	1.6	1.1	4.3	1.5	16.1
TCO, mg/m^3	0.7	0.2	0.4	1.2	1.0	0.7	0	4.1
GRAV, mg/m^3	0.3	5.5	0.5	0.4	0.1	3.6	1.5	12.0

Category	Assigned Intensity - mg/(m^3)							
Aliphatic Hydrocarbons	100/0.2	100/2.8	100/0.4	QNS*	-	-	-	3.4
Halogenated Aliphatics	100/0.2				-	-	-	0.2
Aromatic Hydrocarbons	100/0.2**	100/2.8	100/0.5		-	-	-	3.5
Halogenated Aromatics	100/0.2**				-	-	-	0.2
Silicones	-				100/0.2**	-	-	0.2
Heterocyclic O Compounds	-				-	-	-	-
Nitroaromatics	-				10/0.02	-	-	0.02
Ethers	-				10/0.02	-	-	0.02
Aldehydes	-				10/0.02	-	-	0.02
Phosphates	-				10/0.02	10/0.11	10/0.04	0.17
Nitriles	-				10/0.02	-	-	0.02
Heterocyclic N Compounds	-				10/0.02	10/0.11	10/0.04	0.17
Heterocyclic S Compounds	-				10/0.02	-	-	0.02
Alcohols	100/0.2**				10/0.02	100/1.1	100/0.4	1.42
Phenols	100/0.2**				10/0.02	10/0.11	10/0.04	0.17
Ketones	-				100/0.2	100/1.1	100/0.4	1.7

(Continued)

*Quantity Not Sufficient.

**Possible Contamination.

TABLE 35. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. A2-X

Category	Assigned Intensity - mg/(m^3)							
Amines	-	QNS*	QNS*	QNS*	10/0.02	10/0.11	10/0.04	0.17
Alkyl S Compounds	-				10/0.02	10/0.11	10/0.04	0.17
Sulfuric Acids	-				10/0.02	10/0.11	10/0.04	0.17
Sulfoxides	-				10/0.02	10/0.11	10/0.04	0.17
Amides	-				10/0.02	10/0.11	10/0.04	0.17
Carboxylic Acids	-				10/0.02	10/0.11	10/0.04	0.17
Esters	-				100/0.2	100/1.1	100/0.4	1.7

*Quantity Not Sufficient.

TABLE 36 ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. A2-SWD

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/L	3.4	3.9	2.9	1.2	0.7	0.9	0.5	13.6
TCO, mg/L	0.2	0.1	0	0	0	0	0	0.3
GRAV, mg/L	3.2	3.8	2.9	1.2	0.7	0.9	0.5	15.3

Category	Assigned Intensity - mg/L							
Aliphatic Hydrocarbons	100/1.7	-	-	-	-	QNS*	QNS*	1.7
Halogenated Aliphatics	100/1.7	100/1.26	-	-	-			2.96
Aromatic Hydrocarbons	-	100/1.26	100/0.57	-	-			1.83
Halogenated Aromatics	-	100/1.26	100/0.57	-	-			1.83
Silicones	-	10/0.13	10/0.06	10/0.07	-			0.26
Heterocyclic O Compounds	-	-	100/0.57	10/0.07	-			0.64
Nitroaromatics	-	-	-	10/0.07	10/0.04			0.11
Ethers	-	-	-	100/0.67	10/0.04			0.71
Aldehydes	-	-	-	10/0.07	10/0.04			0.11
Phosphates	-	-	-	10/0.07	10/0.04			0.11
Nitriles	-	-	-	10/0.07	10/0.04			0.11
Heterocyclic N Compounds	-	-	-	10/0.07	10/0.04			0.11
Heterocyclic S Compounds	-	-	-	10/0.07	10/0.04			0.11
Alcohols	-	-	-	-	10/0.04			0.04
Phenols	-	-	-	-	10/0.04			0.04
Ketones	-	-	100/0.57**	-	10/0.04			0.61

(Continued)

*Quantity Not Sufficient.

**Possible Contaminant.

TABLE 36. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. A2-SWD (Cont'd)

Category	Assigned Intensity - mg/L							
Amines	-	-	-	-	10/0.04	QNS*	QNS*	0.04
Alkyl S Compounds	-	-	-	-	10/0.04			0.04
Sulfuric Acids	-	-	-	-	10/0.04			0.04
Sulfoxides	-	-	-	-	10/0.04			0.04
Amides	-	-	-	-	10/0.04			0.04
Carboxylic Acids	-	-	-	-	10/0.04			0.04
Esters	-	-	100/0.57**	-	10/0.04			0.61

*Quantity Not Sufficient.

**Possible Contaminant.

benzo(a)pyrene, dibenzofluorene, indeno(1,2,3-cd)pyrene, dibenzanthracene, and dibenzochrysene isomer, respectively.

These data indicate that carcinogenic compounds possibly are being emitted to the atmosphere from the furnace and that although the scrubber is reasonably ineffective for organic compound removal, it is trapping many of the possibly carcinogenic, high molecular weight compounds.

12.1.8 Plant A Final Wastewater Discharge

All wastewater from the plant flows into about 100 acres of ponds where solids settle before the water is discharged to the river. The solids are occasionally dredged out and landfilled on company property. A grab sample of the pond effluent (17.03 m^3/min, 4500 gpm) was taken the same day furnace A-2 was tested. The sample was filtered for suspended solids determination, extracted and subjected to LC, IR, TCO, GRAV, and LRMS analysis. The overall results for solids and organics are summarized in Table 37, and the Level 1 organic analysis is summarized in Table 38. The LC, IR, and LRMS data are in the appendices.

The organic compounds found are predominately high molecular weight aliphatics. No evidence was found for carcinogenic compounds.

12.1.9 Plant A Summary

Sampling was conducted to compare the two furnaces, one using undercover combustion (A-1) and one of open design (A-2), producing high carbon ferromanganese. The results, Table 39, indicate that furnace A-1 more effectively destroys organic compounds. However, a definitive conclusion cannot be drawn because secondary emissions from furnace A-1, which were substantial, were not sampled. Assuming (see Table 2 for basis of assumption) that both furnaces generate particulate at the same rate (11.07 kg/Mw-hr), emissions from furnace A-1 secondary control system would be 6.92 kg/Mw-hr (62.5 percent of total dust generated) or 78.9 kg/hr. However, since organics are only 1.5 percent of the particulate mass generated by furnace A-1 and 3.1 percent of the particulate for furnace A-2, there is evidence that less organic is emitted from furnace A-1 (on a kg/Mw-hr basis).

Detailed analysis indicated carcinogenic compounds were not being emitted to the atmosphere from furnace A-1. Potential presence of carcinogenic compounds was found in the scrubber water, however, and in emissions to the air

TABLE 37. PLANT A FINAL EFFLUENT

Sample Point - Near plant effluent discharge point.

Total Plant Discharge Flow Rate: 17.034 m^3/min (4500 gpm)

Component	Weight Collected, mg	Concentration mg/L	Kg Emitted per Hour
Suspended Solids	36	9.4	9.6
Organics*	13.3	6.65	6.8

*22 Percent of the organic is adsorbed on the suspended solids.

93.6 Percent of the organic is concentrated in LC fraction 3.

IR and LRMS indicate the organic has no aromatic structure and is predominately high molecular weight aliphatic compound.

TABLE 38. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. A-PE

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/L	0	0.25	20.4	0.35	0	0.6	0.25	21.8
TCO, mg/L	0	0	0	0	0	0	0	0
GRAV, mg/L	0	0.25	20.4	0.35	0	0.6	0.25	21.8

Category	Assigned Intensity - mg/L							
Aliphatic Hydrocarbons	-	100/0.25	100/4.7	QNS*	QNS*	-	QNS*	4.7
Halogenated Aliphatics	-		100/4.7			-		4.95
Aromatic Hydrocarbons	-		10/0.5			-		0.5
Halogenated Aromatics	-		10/0.5			-		0.5
Silicones	-		100/4.7			-		4.7
Heterocyclic O Compounds	-		10/0.5			-		0.5
Nitroaromatics	-		-			-		
Ethers	-		-			-		
Aldehydes	-		-			-		
Phosphates	-		-			10/0.005		0.005
Nitriles	-		-			-		
Heterocyclic N Compounds	-		-			10/0.005		0.005
Heterocyclic S Compounds	-		-			10/0.005		0.005
Alcohols	-		-			10/0.005		0.005
Phenols	-		-			10/0.005		0.005
Ketones			100/4.7**			10/0.005		4.705

(Continued)

*Quantity Not Sufficient. **Possible contamination.

TABLE 38. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. A-PE (Cont'd)

Category	Assigned Intensity - mg/L							
Amines	–	QNS*	–	QNS*	QNS*	10/0.005	QNS*	0.005
Alkyl S Compounds	–		–			10/0.005		0.005
Sulfuric Acids	–		–			10/0.005		0.005
Sulfoxides	–		–			10/0.005		0.005
Amides	–		–			10/0.005		0.005
Carboxylic Acids	–		–			10/0.005		0.005
Esters	–		–			10/0.005		0.005

*Quantity Not Sufficient.

TABLE 39. EMISSION COMPARISON, FURNACES A-1 AND A-2

Furnace No.	Component	Emissions to Atmosphere			Total Generated[a]		
		kg/hr	kg/Mw-hr	kg/Mg Alloy	kg/hr	kg/Mw-hr	kg/Mg Alloy
A-1	Particulate	0.76	0.067	0.16	47.3	4.1	10.14
A-2	Particulate	5.32	0.337	0.79	174.9	11.07	26.0
A-1	Organics	0.31	0.027	0.066	0.72	0.063	0.15
A-2	Organics	4.60	0.29	0.68	5.49	0.35	0.82

[a] Sum of component in scrubber discharge gas and scrubber water. It does not include secondary emissions from furnace A-1. Hood design for furnace A-2 collects essentially all of the furnace gas and fume.

and in the scrubber water from furnace A-2. No evidence for carcinogenic compounds was found in the final plant wastewater discharge. This, of course, raises the question as to whether the carcinogenic compounds indicated in the scrubber water were destroyed or whether they accumulated in the sludge (subsequently dredged out and landfilled by the company).

A major difference in the emission control systems for the two furnaces is the volume of air that is scrubbed. Furnace A-1 scrubbed gas volume is only 255.1 Nm^3/min (9010 DSCFM) (does not include secondary emission control system) while 3196.4 Nm^3/min (112,879 DSCFM) are scrubbed in the A-2 furnace system. Fan horse power requirements are 250 for furnace A-1 and 2500 for furnace A-2.

12.2 PLANT B TESTS

Sampling at Plant B was conducted to compare different type furnaces producing 50 percent ferrosilicon (50 percent FeSi). Furnace B-1 is a typical open furnace design that allows combustion of furnaces gases as they leave the furnace. Furnace B-2 is a tightly sealed, mix-sealed type furnace. Essentially no combustion of the furnace gas occurs in furnace B-2. There are two primary differences in the operation of the two furnaces. One is the difference in combustion of furnaces gases noted above. The second is in the type of pollution control equipment and gas volume treated by this equipment. Furnace B-1 is serviced by a baghouse while a high pressure drop venturi scrubber is used on furnace B-2. The gas volume from furnace B-1 is substantially greater than that from furnace B-2 because a large amount of air is drawn in during combustion.

12.2.1 Plant B General Description

The plant is located near Lake Erie. Unclarified lake water is used for furnace cooling and gas scrubbing. Treated wastewater from the plant is discharged to the lake.

All raw materials (coal, coke, limestone, gravel, iron scrap, quartz, and wood chips) are stored in the open on the ground (no concrete pads). Products are normally stored inside although a few small piles are on concrete pads outside. All solid wastes from the plant are landfilled on plant property.

This includes wood and iron scrap as well as slag and sludges from gas cleaning. Final wastewater treatment occurs on plant property in about 20 acres of ponds. Treatment includes solid settling and alkaline chlorination for cyanide and phenol destruction. Solids are dredged from the pond and landfilled.

In Table 40 below are some details on the furnaces. The furnace numbers are not consistent with test number, i.e., test B-1 is not on furnace number 1.

TABLE 40 . SUBMERGED ARC FURNACES

Furnace No.	Type	Mw Rating	Pollution Control	Product
1	Mix-sealed	18	Scrubber and Baghouse	50% FeSi
2	Mix-sealed	22	Individual Scrubbers Baghouse for Secondary Dust Common for	CaC_2
3	Mix-sealed	22	Nos. 2 and 3.	CaC_2
4	Mix-sealed	45	Scrubber-Baghouse for Secondary Dust Common with Furnace No.5 Baghouse	50% FeSi
5	Open	45	Baghouse	50%FeSi

All operating mix-sealed furnaces have wet scrubbers to clean the primary undercover furnace gas. The cleaned gas, about 80 percent CO, is collected in a common header. The collected gas is used as fuel in the lime kiln (converts limestone to CaO for use in CaC_2 production). About 170 m^3/min (6000 CFM) and 28 m^3/min (1000 CFM) of the gas is produced in FeSi furnace No. 4 and CaC_2 furnaces Nos. 2 and 3, respectively. The lime kiln uses only about 127 m^3/min (4500 CFM). The 43 m^3/min (1500 CFM) excess gas from furnace No. 4 is flared. All secondary dusts (above mix-seals, packing, grinding, etc.) are collected in baghouses. Gas produced in open furnace No. 5 is also cleaned in a baghouse (common with secondary dust from mix-seals of furnace No. 4). All dust collected is slurried with water in small buildings near each baghouse. The slurry is treated in clarifier-thickeners with the thickener underflow going to the treatment ponds referred to above.

Calcium Carbide Furnaces

The calcium carbide furnaces are housed in a common building. Both are mix-sealed type and have secondary fume hoods above the mix-seals. These hoods go to a common baghouse, rated at 5100 m^3/min (180,000 ACFM) at 107°C (225°F), using Nomex bags. Primary undercover furnace gases are cleaned by Buffalo Forge scrubbers, (rated at 57 m^3/min (2000 ACFM) 54°C (130°F) - recycle water, 1.7 m^3/min (450 gpm) blowdown, collection efficiency reported to be 99^+percent) two for each furnace - one operating, one spare. Hoods, about 2.4 m x 2.4 m (8' x 8'), are used to capture tapping fumes. Fume collection in all areas was good. Collection of tap fumes was the poorest but we estimate about 80 percent capture in this area.

Raw materials, 3,175 kg/hr (7,000 lbs/hr) lime, 1,814 kg/hr (4,000 lbs/hr) coke are delivered to each furnace cover by chutes positioned around the three hollow center self-baking electrodes. Lime fines are blown into the furnaces through the hollow center electrodes by recycled CO gas.

The calcium carbide furnaces are tapped continuously. Circular casting wheels are used. Combined production of the furnaces is about 6,800 kg/hr (15,000 lbs/hr).

Lime Kiln

Carbon monoxide gas produced in the furnaces is used as a fuel in the calcination of limestone. Kiln temperature is about 1,260°C (2,300°F). The exhaust gas, containing about 4 percent oxygen and 1 to 1 1/2 percent combustible gases is cleaned in a Pease Anthony wet scrubber. The operation was clean and well operated.

Wastewater System

Wastewaters originate from the various wet scrubbers and slurrying of collected baghouse dust. All water from furnace 4 goes to a single clarifier where the solids are thickened. The clarifier overflow is returned to the process for reuse. Thickened sludge from the clarifier is pumped to the west settling pond. Carbide furnace scrubber water, lime kiln scrubber water, and carbide baghouse slurry are collected and pumped to the east settling pond. Solids settle out in the two ponds and are dredged and pumped to the landfill site. The water leaving these ponds is chlorinated at an appropriate pH for cyanide and phenol destruction. The CaC_2 furnaces produce most of the plants raw cyanide load and most of the phenol comes from the FeSi furnaces.

12.2.2 Furnace B-1 Description

Furnace B-1, Figure 5, is an open design, loosely hooded furnace producing 50 percent FeSi. The fume hood extends to within about 2-3 meters (6-9 feet) of the furnace and collects all gases and fumes generated by the furnace. There are doors on the hood that can be closed to reduce the amount of air drawn into the system but they are frequently, if not usually, open. Tapping fumes are controlled by a small hood immediately above the tap hole and a large, mobile hood that can be positioned to cover the ladle and the tap hole lip. Fume capture in all areas was good although some fume does escape the tapping hood system. Tapping occurs about every 70 minutes and lasts about 15 minutes. Gases exhausted to the baghouse (from the furnace hood) first pass through a cyclone for heavy solids removal and then through a radiant cooling section (a series of large diameter U-shaped pipes).

Power is supplied to the furnace through three submerged 1.52 meter (60 inch) diameter Soderberg carbon electrodes arranged in a triangular pattern. Pre-mixed feed materials are gravity fed into the furnace from overhead storage bins. The furnace operations are highly instrumented and a significant amount of the operation is under computer control. The furnace typically operates at about 52.5 Mw and produces about 245 Mg (270 tons) of product per 24 hours of operation. There is no slag (in the normal usage of the word) produced in this operation. There is a "Dross" produced (less than 2 percent of total production) composed of Al_2O_3, CaO, SiC, SiO_2 and other unreacted mix compounds.

Gases collected from the furnace exit the building at a temperature of about 355°C (670°F) and are cooled (noted above) before going to the baghouse. The baghouse contains 14 compartments which are cleaned in sequence. It is designed to handle 13,450 m^3/min at 204°C (475,000 ACFM at 400°F). Thirty percent of the gas flow to the baghouse is from the secondary fume control system of furnace B-2. Gas from furnace B-2 joins the gas from furnace B-1 just before entering the baghouse.

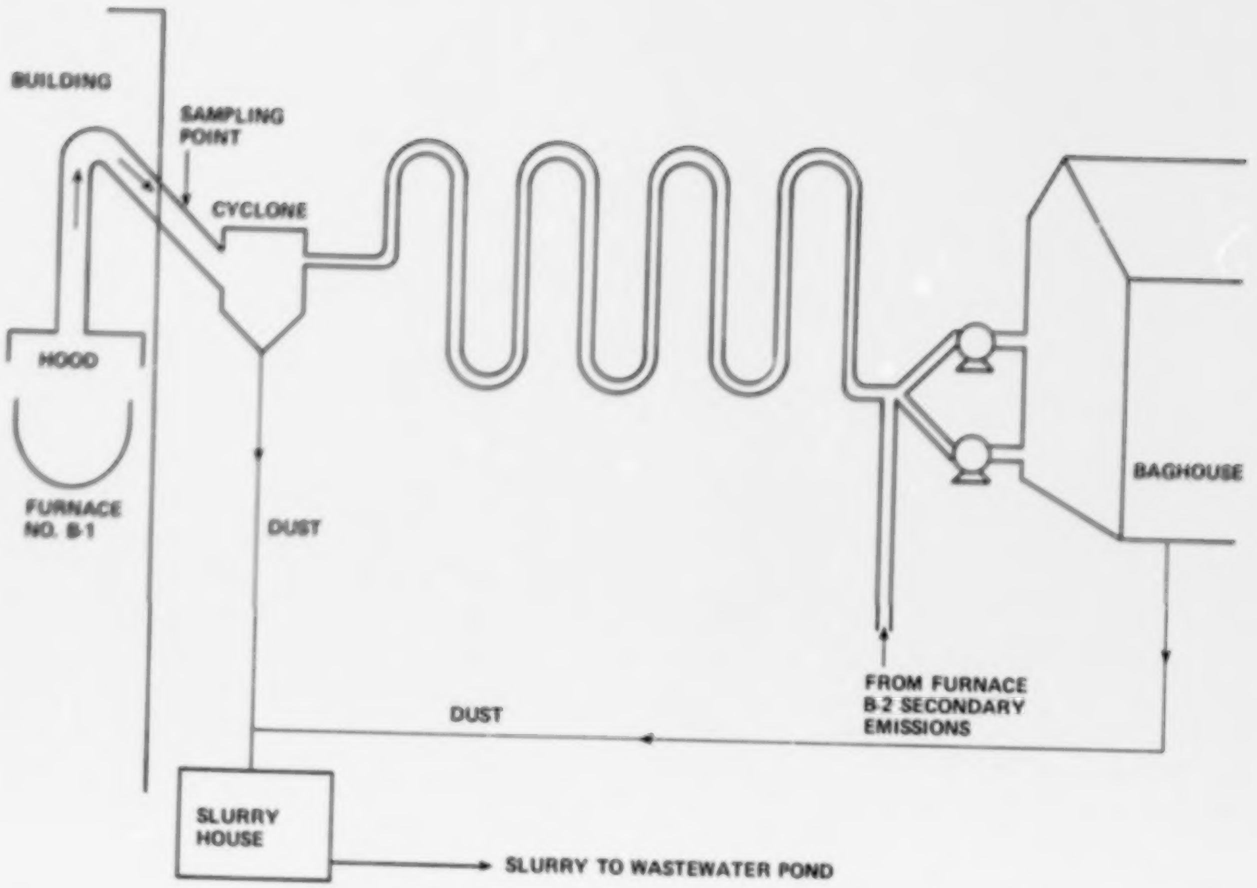
BUILDING
SAMPLING POINT
CYCLONE
HOOD
FURNACE NO. B-1
DUST
BAGHOUSE
FROM FURNACE B-2 SECONDARY EMISSIONS
DUST
SLURRY HOUSE
SLURRY TO WASTEWATER POND

Figure 5. Emission control system furnace B-1.

12.2.3 Test Description, Furnace B-1

The source assessment sampling system (SASS) was used to sample the gas and fume collected by the main hood system on furnace B-1. The sample point (see Figure 5) was in the duct about 15 meters (50 feet) upstream of the cyclone (used to remove large particles before the gas goes through the radiant cooling section). Therefore, this sample is a measure of the furnace gases before any emission control. The baghouse discharge was not sampled because a representative, and meaningful sample could not be obtained.

Prior to the SASS test a velocity profile was determined on the 3.048 meter (10 feet) duct with the following results:

ΔP Maximum - 0.28 cm Hg (1.5 inches water)
ΔP Minimum - 0.22 cm Hg (1.2 inches water)
ΔP Average - 0.24 cm Hg (1.31 inches water)
Duct Temperature - 348°C (658°F)
Duct Area 7.29 m^2 (78.5 ft^2)
Moisture 1 percent
Gas Velocity 1,708 m/min (5,604 ft/min)
Flow Rate, Actual 12,467 m^3/min (440,255 ft^3/min)
Flow Rate, Standard Condition 5,750 m^3/min (203,052 ft^3/min)

An Orsat analysis of the gas taken during the SASS test is presented in Table 41.

TABLE 41. ORSAT ANALYSIS, FURNACE B-1

Component	Percent by Volume
CO	0.0
CO_2	2.8
O_2	18.2
Inerts (N_2)	79.0

Data taken with the SASS train during the actual test are given in Table 42.

TABLE 42. SASS TEST DATA, FURNACE B-1

Date of Test	4/25/79	
Volume of Gas Sampled	13.321 Nm^3	(470.415 DSCF)
Stack Gas, Temperature	348°C	658°F
Pressure	75.74 cm Hg	29.82 inches Hg
Dry Molecular Weight	29.18	
Wet Molecular Weight	28.96	
Moisture, Percent	2.0	
Velocity	28.5 m/sec	(93.4 feet/sec)
Flow Rate	12,467 m^3/min	(440,255 ACFM)
	5,750 Nm^3/min	(203,052 DSCFM)
Total Sampling Time	135 minutes	
SASS Flow Rate	0.0987 Nm^3/min	(3.48 DSCFM)
Percent Isokinetic	100.7	

Raw materials are fed to the furnace from storage bins above the furnace. Pre-weighed and blended mix is delivered to these bins via "trip" cars. Given in Table 43 are the raw mix components and average feed rate from midnight until 2.00 p.m. on the day of the test (testing occurred from 11:15 a.m. until 2:15 p.m.). The average analysis of the alloy produced is given in Table 44.

The furnace was operating at an average load of 48.4 Mw and produced about 9.54 Mg (10.52 tons) of 50 percent FeSi alloy per hour during the test period.

12.2.4 Test Results, Furnace B-1

Particulates

In Table 45, details of the particulate generated by furnace B-1 are given. These data include all particulate directly from the furnace but do not include fumes from tapping, etc. It should be noted that these are not emissions to the atmosphere since the sample point was before the emission control equipment.

The particulate concentration in the gas was 1,364 mg/Nm^3. Of this, 58.6 percent was captured by the ≤1μ filters (submicron dust and fume). Total

TABLE 43. RAW MATERIAL FEED FOR FURNACE B-1

AT 48.4 Mw (9.54 Mg ALLOY/HR)

Component	Pile No.	Kg/Trip	Kg/Hour	Kg/Mw-Hr	Kg Consumed Per Mg Alloy Produced
Reducing Agent					
Rosa Pea Coal	4,521	506	5,207	108	545
Porosity Agents					
Wood Chips	9,050	165	1,698	35	177
Wood Chips	9,555	165	1,703	35	180
Recycle Material					
Briquett Culls	5,687	12	247	5	26
Si Ores					
Sidley Special Gravel	3,101	587	6,037	125	632
Sm.Ind. Min. Qtz.	3,607	357	3,672	76	384
Fe Ores					
Regular Steel	6,382	220	2,268	47	237
Low Cr Steel	6,173	270	2,776	57	290
Electrode	-	-	153	3	16
Total		2,295	23,761	490	2,486

TABLE 44. AVERAGE PRODUCT ANALYSIS, FURNACE B-1

All Values in Percent

Fe	-	49.02	Cr	0.17
Si		49.2	Al	0.44
Mn		0.87	C	0.0
Ca		0.04	Mg	0.0
Sr		0.0	P	0.0
B		0.0	Ca	0.03

TABLE 45. PARTICULATE LEVELS BEFORE CONTROL EQUIPMENT, FURNACE B-1

Sample Point - In duct before any pollution control equipment.

Volume of Gas Sampled: 13.321 NM^3

Sample Type	Weight Collected, mg	Concentration mg/NM^3	Kg generated per Hour	Kg generated per MW-hr	Kg generated per Mg Alloy
Particulate					
Probe	3,733	280.2	96.7	2.00	10.11
10μ Cyclone	2,034.8	152.75	52.7	1.09	5.51
3μ Cyclone	961.2	72.16	24.9	0.514	2.60
1μ Cyclone	778.9	58.47	20.2	0.417	2.11
<1μ Filters	10,662.2	800.41	276.1	5.705	28.87
Total Particulate	18,170.1	1364.02	470.6	9.722	49.20
Organic					
Probe	95.7	7.18	2.48	0.0512	0.26
C 310	5.9	0.44	0.15	0.0032	0.016
C 1F	2.3	0.17	0.06	0.0012	0.0062
Organic Module	358.0	26.88	9.27	0.192	0.97
Total	461.9	34.68	11.96	0.247	1.25

particulate generated by the furnace was 470.6 kg/hr or 9.72 Kg/Mw-hr or 49.2 kg/Mg alloy produced. A baghouse collection efficiency of at least 95.4 percent would be required to meet NSPS of 0.45 kg/Mw-hr for 50 percent FeSi furnaces. (The above calculation does not include tapping fumes which are included in the NSPS requirement of 0.45 kg/Mw-hr particulate emission). Put another way, a baghouse collection efficiency of 99.9 percent would allow 0.35 kg/Mw-hr of particulate to be emitted by tapping operations and still be in compliance with NSPS requirements.

Organics

Details of the organic generated by furnace B-1 are included in Table 45. The concentration of organic matter in the gas was 34.68 mg/Nm^3. The organic module contained 77.5 percent of this organic matter. Since the duct temperature was above 300°C at the sample point, and the SASS cyclones were operated at about 204°C, it is not surprising that little organic was adsorbed on the dust. One could speculate that little of this organic matter is trapped by the baghouse since it operates at about 150°C (300°F) - the actual baghouse temperature was not measured during the test since the plant sensor was not operating.

Level 1 Inorganic Analysis

The SASS particulate catches (probe, 1-3μ cyclone and filter combined, and 3-10μ and >10μ cyclones combined) and the first impinger were analyzed by spark source mass spectroscopy (SSMS) and by atomic adsorption spectroscopy (AAS). The AAS results are presented in Table 46. A summation of the SSMS data obtained is given in Table 47, and the individual sample SSMS data are given in Tables 48-52. The original SSMS analysis data are given in the Appendix D. The data in Tables 47-52 are given as concentration of the elements in the furnace gas at the sampling point in μg/m^3. The data given in Appendix D are the concentration of the elements in the sample collected.

Level 1 Organic Analysis

The SASS train catch was analyzed for organic compound categorization as follows:

TABLE 46. FURNACE B-1, Hg, As, Sb[a] ANALYSIS BY AAS

Sample Type	Hg	Concentration in Stack Gas μg/Nm^3	mg per Mw-hr
Probe Solids	0.85 μg/gm	0.24	1.70
3,10μ Cyclones	0.49 μg/gm	0.11	0.79
<1μ Filter 1μ Cyclone	<0.1 μg/gm	<0.086	<0.6
Impinger 1	0.47 μg/L[b]	0.017	0.12
Impingers 2 and 3 combined	0.76 μg/L[c]	0.094	0.67
Total		<0.55	<3.9

[a] No arsenic or antimony was detected in the impinger samples. Detection limits: 0.015 μg/mL, As, 0.005 μg/mL , Sb.

[b] Total sample volume 480 mL

[c] Total sample volume 1650 mL.

TABLE 47. FURNACE B-1, SSMS ANALYSIS SUMMARY

Element	μg/Nm^3 Concentration	Kg generated per Mw-hr	Element	μg/Nm^3 Concentration	Kg generated per Mw-hr
Uranium	≤141.3	≤1,007	Terbium	≤0.18	≤1.3
Thorium	≤185.1	≤1,319	Gadolinium	≤1.3	≤9.3
Bismuth	83.6	596	Europium	0.5	3.6
Lead	>1,700*	12,100	Samarium	2.4	17
Thallium	≤7.6	≤54	Neodymium	4.3	31
Mercury	NR		Praseodymium	5.1	36
Gold			Cerium	>126*	>898
Platinum			Lanthanum	37	260
Iridium			Barium	6,555*	>46,700
Osmium			Cesium	8.2	58
Rhenium			Iodine	9.6	68
Tungsten	4.7	34	Tellurium	26.6	190
Tantalum	0.2	1.4	Antimony	363.9	2,594
Hafnium	0.2	1.4	Tin	2,255*	>16,100
Lutecium	0.02	0.14	Indium	STD	
Ytterbium	0.2	1.4	Cadmium	≤255	≤1,810
Thulium	0.04	0.29	Silver	972	6,930
Erbium	0.48	3.4	Palladium		
Holmium	0.5	3.6	Rhodium		
Dysprosium					

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*Major component of at least one sample. Blanks indicate the element was below detection limits.
(Continued)

TABLE 47. (Cont'd)

Element	μg/Nm^3 Concentration	Kg generated per Mw-hr	Element	μg/Nm^3 Concentration	Kg generated per Mw-hr
Ruthenium			Vanadium	14.6	104
Molybdenum	≤57.2	≤408	Titanium	>317.7*	>2,265
Niobium	1.6	11	Scandium	≤ 25.4	≤181
Zirconium	7.1	51	Calcium	MC*	MC
Yttrium	2.3	16	Potassium	>52*	>3,300
Strontium	>747*	>5,300	Chlorine	>130*	>927
Rubidium	119	848	Sulfur	>880*	>6,300
Bromine	2,075	14,800	Phosphorus	MC*	MC
Selenium	48.1	340	Silicon	MC*	MC
Arsenic	>122.3*	>872	Aluminum	>23,142	>164,900
Germanium	210.6	1,501	Magnesium	>1,000*	>7,000
Gallium	473	3,370	Sodium	>359.7*	>2,550
Zinc	MC*	MC	Fluorine	>969*	>6,900
Copper	MC*	MC	Oxygen	NR**	
Nickel	>562*	>4,000	Nitrogen	NR**	
Cobalt	≤ 42.3	≤ 301	Carbon	NR**	
Iron	MC*	MC	Boron	30.3	216
Manganese	>187*	>1,330	Beryllium	≤ 0.19	≤ 1.35
Chromium	>810*	>5,770	Lithium	161.9	1,154
			Hydrogen	NR**	

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*Major component of at least one sample.

**Not reported.

TABLE 48. SSMS ANALYSIS FURNACE B-1, PROBE SOLIDS

Element	Conc. µg/Nm^3	Element	Conc. µg/Nm^3	Element	Conc. µg/Nm^3	Element	Conc. µg/Nm^3
Uranium	≤ 0.2	Terbium	0.008	Ruthenium		Vanadium	6.2
Thorium	2	Gadolinium	≤ 0.6	Molybdenum	10	Titanium	241
Bismuth	13	Europium	0.1	Niobium	0.3	Scandium	0.06
Lead	MC	Samarium	1	Zirconium	2	Calcium	MC
Thallium	3.9	Neodymium	2	Yttrium	1	Potassium	>252
Mercury	NR	Praseodymium	1	Strontium	146	Chlorine	MC
Gold		Cerium	120	Rubidium	39.2	Sulfur	>126
Platinum		Lanthanum	17	Bromine	24	Phosphorus	MC
Iridium		Barium	98.1	Selenium	10	Silicon	MC
Osmium		Cesium	0.8	Arsenic	95.3	Aluminum	>20
Rhenium		Iodine	2.0	Germanium	18	Magnesium	MC
Tungsten	1	Tellurium	3.9	Gallium	67.3	Sodium	>53.2
Tantalum	≤0.2	Antimony	6.4	Zinc	MC	Fluorine	MC
Hafnium		Tin	185	Copper	MC	Oxygen	NR
Lutecium		Indium	STD	Nickel	MC	Nitrogen	NR
Ytterbium		Cadmium	58.8	Cobalt	2	Carbon	NR
Thulium		Silver	21	Iron	MC	Boron	4.2
Erbium	0.08	Palladium		Manganese	>21	Beryllium	0.08
Holmium	0.1	Rhodium		Chromium	MC	Lithium	6.4
Dysprosium	0.2					Hydrogen	NR

STD - Internal Standard NR - Not Reported MC - Major Component

TABLE 49. SSMS ANALYSIS FURNACE B-1, >3μ SOLIDS

Element	Conc. $\mu g/Nm^3$	Element	Conc. $\mu g/Nm^3$	Element	Conc. $\mu g/Nm^3$	Element	Conc. $\mu g/Nm^3$
Uranium	0.2	Terbium	$\leq$ 0.01	Ruthenium		Vanadium	5.4
Thorium	2	Gadolinium	$\leq$ 0.4	Molybdenum	18	Titanium	76.5
Bismuth	5.6	Europium	0.2	Niobium	0.9	Scandium	0.2
Lead	MC	Samarium	0.9	Zirconium	4.3	Calcium	MC
Thallium	0.7	Neodymium	2*	Yttrium	1	Potassium	>200
Mercury	NR	Praseodymium	3.8	Strontium	MC	Chlorine	121
Gold		Cerium	MC*	Rubidium	6.3	Sulfur	>101
Platinum		Lanthanum	17	Bromine	11	Phosphorus	MC
Iridium		Barium	MC	Selenium	4.9	Silicon	MC
Osmium		Cesium	0.4	Arsenic	27	Aluminum	>16
Rhenium		Iodine	3.4	Germanium	3.6	Magnesium	MC
Tungsten	0.7	Tellurium	2.7	Gallium	54*	Sodium	>40.5
Tantalum		Antimony	31.5	Zinc	MC	Fluorine	144
Hafnium	0.2	Tin	65.2	Copper	MC	Oxygen	NR
Lutecium	0.02	Indium	STD	Nickel	151	Nitrogen	NR
Ytterbium	0.2	Cadmium	47.2	Cobalt	0.2	Carbon	NR
Thulium	0.04	Silver	29.2	Iron	MC	Boron	1
Erbium	0.4	Palladium		Manganese	>166	Beryllium	<0.02
Holmium	0.4	Rhodium		Chromium	MC	Lithium	0.4
Dysprosium	0.9					Hydrogen	NR

*Heterogeneous STD - Internal Standard NR - Not Reported MC - Major Component

TABLE 5Q SSMS ANALYSIS FURNACE B-1, <3μ SOLIDS

Element	Conc. μg/Nm^3	Element	Conc. μg/Nm^3	Element	Conc. μg/Nm^3	Element	Conc. μg/Nm^3
Uranium	$\leq$0.8	Terbium		Ruthenium		Vanadium	3
Thorium	$\leq$0.9	Gadolinium	0.3	Molybdenum	29	Titanium	MC
Bismuth	65	Europium	0.2	Niobium	0.4	Scandium	$\leq$ 0.09
Lead	MC	Samarium	0.5	Zirconium	0.7	Calcium	MC
Thallium	3	Neodymium	0.3	Yttrium	0.3	Potassium	MC
Mercury	NR	Parseodymium	0.3	Strontium	421	Chlorine	MC
Gold		Cerium	6	Rubidium	94.5	Sulfur	>653
Platinum		Lanthanum	3	Bromine	40	Phosphorus	MC
Iridium		Barium	455	Selenium	33	Silicon	MC
Osmium		Cesium	7	Arsenic	MC	Aluminum	>105
Rhenium		Iodine	4	Germanium	189	Magnesium	MC
Tungsten	3	Tellurium	20	Gallium	352	Sodium	>266
Tantalum		Antimony	326	Zinc	MC	Fluorine	$\simeq$ 825
Hafnium		Tin	MC	Copper	MC	Oxygen	NR
Lutecium		Indium	STD	Nickel	11	Nitrogen	NR
Ytterbium		Cadmium	77	Cobalt	< 0.09	Carbon	NR
Thulium		Silver	20	Iron	MC	Boron	25
Erbium		Palladium		Manganese	MC	Beryllium	< 0.09
Holmium		Rhodium		Chromium	799	Lithium	15
Dysprosium						Hydrogen	NR

STD - Internal Standard NR - Not Reported MC - Major Component

TABLE 51. SSMS ANALYSIS FURNACE B-1, IMPINGER 1 LIQUID

Element	Conc. µg/Nm^3	Element	Conc. µg/Nm^3	Element	Conc. µg/Nm^3	Element	Conc. µg/Nm^3
Uranium	≤140	Terbium		Ruthenium		Vanadium	
Thorium	≤180	Gadolinium		Molybdenum		Titanium	MC
Bismuth		Europium		Niobium		Scandium	≤25
Lead	1,700	Samarium		Zirconium		Calcium	MC
Thallium		Neodymium		Yttrium		Potassium	MC
Mercury	NR	Praseodymium		Strontium	180	Chlorine	MC
Gold		Cerium		Rubidium	18	Sulfur	MC
Platinum		Lanthanum		Bromine	2,000	Phosphorus	MC
Iridium		Barium	6,000	Selenium		Silicon	MC*
Osmium		Cesium		Arsenic		Aluminum	>23,000
Rhenium		Iodine		Germanium		Magnesium	1,000
Tungsten		Tellurium		Gallium		Sodium	MC
Tantalum		Antimony		Zinc	MC	Fluorine	
Hafnium		Tin	2,000*	Copper	MC	Oxygen	NR
Lutecium		Indium	STD	Nickel	400	Nitrogen	NR
Ytterbium		Cadmium	≤72	Cobalt	≤40	Carbon	NR
Thulium		Silver	900	Iron	MC*	Boron	
Erbium		Palladium		Manganese	MC*	Beryllium	
Holmium		Rhodium		Chromium	11	Lithium	140
Dysprosium						Hydrogen	NR

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*Heterogeneous STD - Internal Standard NR - Not Reported MC - Major Component

TABLE 52. SSMS ANALYSIS FURNACE B-1, IMPINGER 1 SOLIDS

Element	Conc. µg/Nm^3	Element	Conc. µg/Nm^3	Element	Conc. µg/Nm^3	Element	Conc. µg/Nm^3
Uranium	≤ 0.1	Terbium		Ruthenium		Vanadium	
Thorium	≤ 0.2	Gadolinium		Molybdenum	≤ 0.2	Titanium	0.2
Bismuth		Europium		Niobium		Scandium	≤ 0.02
Lead	0.38	Samarium		Zirconium	0.1	Calcium	MC
Thallium		Neodymium		Yttrium		Potassium	MC
Mercury	NR	Praseodymium		Strontium	0.03	Chlorine	8.39
Gold		Cerium		Rubidium	0.01	Sulfur	MC
Platinum		Lanthanum		Bromine	0.43	Phosphorus	0.35
Iridium		Barium	2.1	Selenium	0.2	Silicon	MC
Osmium		Cesium		Arsenic		Aluminum	0.98
Rhenium		Iodine	0.2	Germanium		Magnesium	≤ 0.2
Tungsten		Tellurium		Gallium		Sodium	MC
Tantalum		Antimony		Zinc	1.3	Fluorine	MC
Hafnium		Tin	4.63	Copper	0.06	Oxygen	NR
Lutecium		Indium	STD	Nickel	0.09	Nitrogen	NR
Ytterbium		Cadmium		Cobalt	≤ 0.03	Carbon	NR
Thulium		Silver	2.1	Iron	1.2	Boron	0.09
Erbium		Palladium		Manganese		Beryllium	
Holmium		Rhodium		Chromium	≤ 0.06	Lithium	0.06
Dysprosium						Hydrogen	NR

STD - Internal Standard NR - Not Reported MC - Major Component

Probe solids (B1-PW) - extracted, GRAV, LC, IR.

Particulate filter and 1-3μ cyclone catch - extracted, GRAV not sufficient for LC.

>3μ cyclone catch - extracted, GRAV - not sufficient for LC.

Organic module (B1-X) - extracted, TCO, GRAV, LC, IR, LRMS.

The data obtained are summarized in Tables 53 and 54. The LC, IR, and LRMS data are in the appendices. Of the organic matter captured by the SASS train 77.5 percent was found in the organic module. The probe solids contain 20.7 percent of the total organic captured. All of the organic found on the particulates is GRAV material (Level 1 does not require a TCO on these samples). The organic module catch was also 76.5 percent GRAV material.

The compound categorization of the probe solids organics does not show a predominate concentration of any category. Major categories found were ethers, alcohols, ketones, amines, sulfonic acids, and esters. The concentrations are well below applicable DMEG values.

The compound categorization of the organic module is similar to that found for the particulates except that substantial concentrations of aliphatics, silicones, and fused aromatic hydrocarbons were also found. The LRMS data indicate the possible presence of the carcinogenic compounds benzanthracene, chrysene, and benzopyrene (M/es of 228, 252).

12.2.5 Furnace B-2 Description

Furnace B-2, Figure 6, is a mix-sealed furnace producing 50% FeSi. The unit is a companion to B-1 in size and product. The B-2 furnace is relatively tightly sealed to prevent any appreciable quantity of air being drawn into the furnace gas collection system. As a result, the gas produced by the furnace is about 80 percent CO and most of it is used as fuel in the lime kiln. Furnace power level is about 48 Mw and about 245 Mg (270 tons) of product is made per 24 hours of operation.

The furnace cover fits tightly and "mud" is packed around the opening to prevent air ingression. Feed materials are fed from the overhead storage bins onto the furnace cover so that it provides a partial gas seal of the feed openings around the electrodes. Some furnace fumes escape from around the electrodes during normal operations and can be substantial during furnace "blows." The gas escaping the cover is frequently burning during periods of

TABLE 53. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B1-PW

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/m^3	0.1	0.06	0.06	0.45	0.24	1.47	0.06	2.4
TCO, mg/m^3	0	0	0	0	0	0	0	0
GRAV, mg/m^3	0.1	0.06	0.06	0.45	0.24	1.47	0.06	2.4

Category	Assigned Intensity - mg/(m^3)							
Aliphatic Hydrocarbons	QNS*	-	-	-	-	-	-	
Halogenated Aliphatics		100/0.026	-	-	-	-	-	0.026
Aromatic Hydrocarbons		10/0.003	10/0.002	-	-	-	-	0.005
Halogenated Aromatics		10/0.003	10/0.002	-	-	-	-	0.005
Silicones		10/0.003	10/0.002	10/0.01	-	-	-	0.015
Heterocyclic O Compounds		-	10/0.002	10/0.01	-	-	-	0.012
Nitroaromatics		-	-	10/0.01	10/0.005	-	-	0.015
Ethers		100/0.026**	_	100/0.09	100/0.05	-	-	0.166
Aldehydes		-	-	10/0.01	10/0.005	-	-	0.015
Phosphates		-	-	10/0.01	10/0.005	10/0.03	10/0.002	0.047
Nitriles		-	-	10/0.01	10/0.005	-	-	0.015
Heterocyclic N Compounds		-	-	10/0.01	10/0.005	10/0.03	10/0.002	0.047
Heterocyclic S Compounds		-	-	10/0.01	10/0.005	-	-	0.015
Alcohols		-	100/0.02**	100/0.09**	10/0.005	100/0.26	10/0.002	0.377
Phenols		-	-	-	10/0.005	10/0.03	10/0.002	0.377
Ketones		-	-	100/0.09**	100/0.05	100/0.26	100/0.02	0.42

(Continued)

*Quantity Not Sufficient.

**Possible Contamination.

TABLE 53. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B1-PW, (Cont'd)

Category	Assigned Intensity - mg/m^3)							
Amines	QNS*	-	100/0.02**	100/0.09**	10/0.005	100/0.26	10/0.002	0.377
Alkyl S Compounds		-	-	-	10/0.005	10/0.03	10/0.002	0.037
Sulfuric Acids		-	-	-	10/0.005	100/0.26	10/0.002	0.267
Sulfoxides		-	-	-	10/0.005	10/0.03	10/0.002	0.037
Amides		-	-	-	10/0.005	10/0.03	10/0.002	0.037
Carboxylic Acids		-	-	-	10/0.005	10/0.03	10/0.002	0.037
Esters		-	100/0.02**	-	100/0.05	100/0.26	100/0.02	0.35

*Quantity Not Sufficient. **Possible Contamination.

TABLE 54. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B1-X

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/m^3	2.9	2.5	4.1	1.2	1.2	0.8	0.7	13.4
TCO, mg/m^3	2.3	0.7	0.7	0.4	0.8	0.1	0	5.0
GRAV, mg/m^3	0.6	1.8	3.4	0.8	0.4	0.7	0.7	8.4

Category	Assigned Intensity - mg/(m^3)							
Aliphatic Hydrocarbons	100/0.58	-	-	QNS*	-	-	-	0.58
Halogenated Aliphatics	100/0.58	100/0.63	-		-	-	-	1.21
Aromatic Hydrocarbons	100/0.58**	100/0.63	100/1.03		-	-	-	2.24
Halogenated Aromatics	100/0.58**	100/0.63	100/1.03		-	-	-	2.24
Silicones	100/0.58**	100/0.63	100/1.03		-	-	-	2.24
Heterocyclic O Compounds	-	-	100/1.03		-	-	-	1.03
Nitroaromatics	-	-	-		10/0.023	-	-	0.023
Ethers	-	-	-		10/0.023	-	-	0.023
Aldehydes	-	-	-		10/0.023	-	-	0.023
Phosphates	-	-	-		100/0.23	10/0.021	10/0.023	0.274
Nitriles	-	-	-		10/0.023	-	-	0.023
Heterocyclic N Compounds	-	-	-		10/0.023	10/0.021	10/0.023	0.067
Heterocyclic S Compounds	-	-	-		10/0.023	-	-	0.023
Alcohols	-	-	-		10/0.023	100/0.21	10/0.023	0.256
Phenols	-	-	-		10/0.023	10/0.021	10/0.023	0.067
Ketones	-	-	-		100/0.23	10/0.021	100/0.23	0.481

(Continued)

*Quantity Not Sufficient. **Possible Contamination.

TABLE 54. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B1-X, (Cont'd)

Category	Assigned Intensity - mg/(m^3)							
Amines	-	-	-	-	10/0.023	100/0.21	10/0.023	0.256
Alkyl S Compounds	-	-	-	-	10/0.023	10/0.021	10/0.023	0.067
Sulfuric Acids	-	-	-	-	10/0.023	10/0.021	10/0.023	0.067
Sulfoxides	-	-	-	-	100/0.23	10/0.021	10/0.023	0.274
Amides	-	-	-	-	100/0.23	100/0.21	10/0.023	0.463
Carboxylic Acids	-	-	-	-	10/0.023	10/0.021	10/0.023	0.067
Esters	-	-	-	-	10/0.023	10/0.021	100/0.23	0.274

*Quantity Not Sufficient.

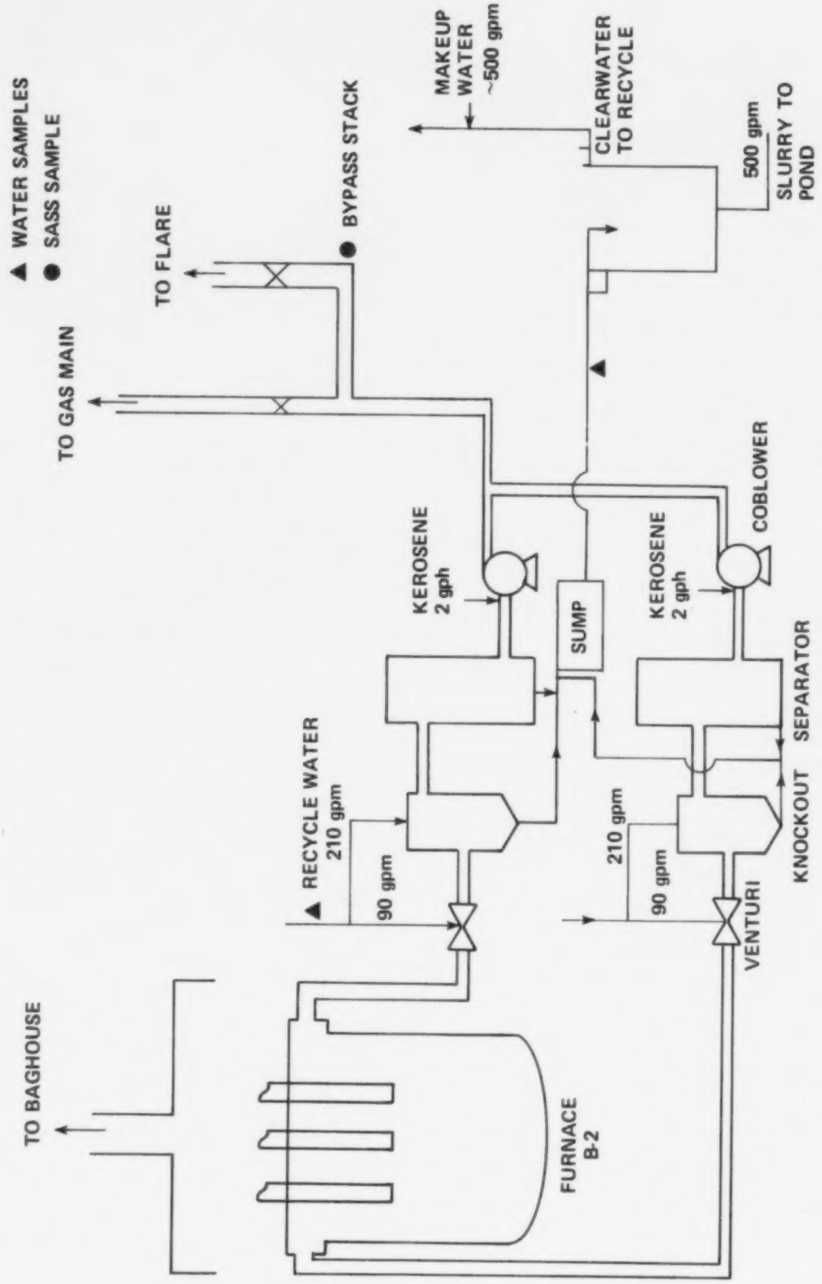
▲ WATER SAMPLES
● SASS SAMPLE
TO GAS MAIN
TO FLARE
BYPASS STACK
MAKEUP WATER ~500 gpm
CLEARWATER TO RECYCLE
500 gpm
SLURRY TO POND
TO BAGHOUSE
RECYCLE WATER 210 gpm
90 gpm
KEROSENE 2 gph
SUMP
KEROSENE 2 gph
COBLOWER
210 gpm
90 gpm
FURNACE B-2
VENTURI
KNOCKOUT
SEPARATOR

Figure 6. Emission control system, furnace B-2.

heavy fuming. There is a hood above the furnace cover to collect these fumes and fumes released during furnace outages, when the seal is broken, and when electrode length is being determined. These collected secondary fumes go to the baghouse which collects particulate generated by furnace B-1.

The primary fume collection system draws gas and fumes from beneath the furnace cover. Gases are withdrawn from the furnace at two points, 180 degrees apart. Two high pressure drop venturi scrubbers (one on each side) clean the gas. A water knockout and separation follow the scrubbers. About 4 - 12 liters (1-3 gallons) per hour of kerosene is injected into the gas stream at the fans (CO blowers) to assist in keeping the fan blades clean. The cleaned furnace gas is forced into the gas main (maintained at about 89 cm of Hg (2.5 PSIG). Most of this gas (∿75 percent) goes to the lime kiln. The excess goes through a bypass stack to a flare. All water from the scrubbers is collected in a common sump and flows to a clarifier. Underflow from the clarifier flows to a wastewater pond. Overflow (essentially free of suspended solids) is recycled to the scrubbers. Makeup water (clarified lake water) is added to the clarifier overflow.

12.2.6 Test Description, Furnace B-2

Samples were taken (see Figure 6 for sampling points) of the cleaned gases from the scrubbers and of the scrubber feed and discharge water. The sampling point for the gas sample was in the 35.56 cm (14 inches) ID gas main bypass duct just before the pressure control damper. The sample was taken with the SASS train. A special probe was used for access through the 2 cm (0.75 inch) port. Pitot tubes were not used because of the small port, thus velocity measurements were not made. Gas flow rate was supplied by the company (estimated accurate to ± 30 percent). Since the stack was under pressure, the probe was equipped with a pressure gauge and valve to prevent pressurizing the SASS system. Provisions were also made to introduce nitrogen into the probe to flush all air out of the system before the high CO content stack gas was admitted to the system. The cyclones were not used (since they tend to leak, they represent an explosion hazard) and the probe was connected directly to the <1μ filter which was maintained at 110°C (230°F).

Water samples were collected during the SASS sampling. A total of 8 liters (2 gallons) of the scrubber feed water was collected from a valve near the venturi. About one-third of the sample was collected at the end of each hour of SASS sampling. A total of 8 liters was taken of the combined scrubber discharge water at the lift station to the clarifier (about one-third collected after each hour of SASS sampling).

Raw material consumption (average during normal operation 12 hours preceding the sampling) and composition are given in Table 55. Operating at 48.0 Mw, the furnace produces about 9.7 Mg (10.7 tons) of 50 percent FeSi product per hour. The average product analysis is given in Table 56.

During the test period the furnace operated at 48.0 Mw. The scrubbers were each operating with a 15 cm of Hg (81 inches of water) pressure drop. Each of the 100 hp CO blowers (240 V-310 AMP) was operating at about 280 amperes. Water flow to each scrubber system was 0.34 m^3 (90 gpm) to the venturi and 0.8 m^3 (210 gpm) to the water knockout (total 2.3 m^3 (600 gpm) for both scrubbers). Gas main pressure was 86.4 cm of Hg (2.49 PSIG).

The probe was inserted into the duct during a furnace outage shortly before testing began. After verifying that the furnace was operating normally, sampling was initiated. A net sampling time of 165.9 minutes was obtained in the 220 minute sample period. Sampling was terminated when a SASS system pump failed.

12.2.7 Test Results, Furnace B-2

On-Site Results

Neither a velocity traverse nor Orsat analysis was obtained because of safety restrictions and lack of Pitot tubes on the modified SASS probe. Gas flow reported by the company was: total gas flow from furnace, 170 m^3/min (6000 ACFM); 42.5 m^3/min (1500 ACFM) through the bypass. The reported gas composition was 85 percent CO, 15 percent CO_2.

Data taken with the SASS train (and company supplied data) during the test are given in Table 57.

Particulate

The amounts of particulate generated by, captured by scrubbers, and escaping the scrubbers of furnace B-2 are given in Table 58. It should be noted that these data apply only to particulates in the primary control system. It should also be noted that these data are for the scrubbed gas (B-1 data was

TABLE 55. RAW MATERIAL FEED FOR FURNACE B-2

AT 48.0 Mw (9.71 Mg ALLOY/HR)

Component	Pile	Kg/Trip	Kg/Hr	Kg/Mw-Hr	Kg Consumed Per Mg of Alloy Produced
Reducing Agent					
Jewel Coal	4,519	509	3,902	81	403
Cleveland Coke	5,326	89	684	14	70
Cleveland Coke	5,325	137	1,046	22	108
Miscellaneous					
Borax	9,690	5	35	1	4
Si Ores					
Ind. Min. Quartz	3,508	347	2,654	55	275
Sidley Spec. Gravel	3,101	409	3,131	65	324
Sidley Reg. Gravel	3,202	355	2,717	57	282
Sm Ind Min Qtz	3,607	244	1,862	39	194
Fe Ores					
6700 Tin Can	6,700	197	1,508	31	156
LO CR Steel	6,173	587	4,496	94	466
Electrode	-	-	136	3	14
Total		2,878	22,171	462	2,294

TABLE 56. AVERAGE PRODUCT ANALYSIS, FURNACE B-2

Component	Percent (Wt)	Component	Percent (Wt)
Si	46.7	Ce	0
Fe	51.7	Mg	0
Mn	0.05	P	0
Ca	0.03	Cu	0.04
Cr	0.06	Sr	0
Al	0.7	B	0

TABLE 57. SASS TEST DATA, FURNACE B-2

Date of Test	5/1/79	
Volume of Gas Sampled	14.4018 Nm^3	(508.595 DSCF)*
Stack Gas, Temperature	51.7°C	(125°F)
Pressure	86.4 cm Hg	(34.01 in Hg (abs))
Dry Molecular Weight	30.4	
Wet Molecular Weight	28.66	
Moisture, Percent	14	
Velocity (calc.)	7.16 meters/sec	(23.5 FPS)
Flow Rate in Bypass	37.49 Nm^3/min	(1324 DSCFM)
	42.48 m^3/min	(1500 ACFM)
Flow Rate, Total	149.97 Nm^3/min	(5296 DSCFM)
	169.9 m^3/min	(6000 ACFM)
Total Sampling Time	165.9 minutes	
SASS Flow Rate	0.0866 Nm^3/min	3.06 SCFM
Percent Isokinetic	100.6	

*20°C (68°F), 76.0 cm Hg (29.92 in Hg)

TABLE 58. PARTICULATES, FURNACE B-2

Particulate not captured by the scrubber

Sample Point - Bypass stack after venturi scrubbers.

Volume of Gas Sampled: 14.4018 NM^3

Sample Type	Weight Collected, mg	Concentration mg/NM^3	Kg[a] per Hour	Kg per MW-hr	Kg per Mg Alloy
Probe	493.3	34.25	0.31 (0.077)	0.0064 (0.0016)	0.03 (0.008)
<1μ Filters (No Cyclones)	3,090.2	214.57	1.93 (0.48)	0.04 (0.01)	0.20 (0.05)
Total	3583.5	248.82	2.24 (0.56)	0.05 (0.01)	0.23 (0.06)

Particulate captured by the scrubber

Sample Point - At inlet to venturi and at scrubber discharge clarifier lift station.

Sample Type	Weight Solids Collected, mg	Concentration mg/L	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Scrubber Inlet	32.0	8.23	1.12	0.02	0.12
Scrubber Discharge	13,050	3277.2	446.6	9.3	46
Net Scrubber Solids		3269	445.4	9.3	46
Total Solids going to the Primary Control System			447.7	9.3	46
% Scrubber Efficiency, Solids			99.5		

[a] Scrubber exhaust gas is split, one-fourth goes to a bypass flare, three-fourths to gas combustion equipment for other process uses. Numbers in parentheses are the amounts actually exhausted to the environment (not counting destruction by the flare).

before emission control) and that for this furnace only one-fourth of the total gas flow is actually discharged to the atmosphere, and this is flared (three-fourths of the gas goes to the lime kiln).

Particulate concentration in the scrubbed gas was 248.8 mg/Nm^3 or 2.24 kg/hr escaping the scrubber. The scrubber captured an additional 445.4 kg/hr of particulate matter or 99.5 percent of the particulate collected by the primary emission control system. Particulate concentration before the scrubber was, therefore, 49,750 mg/Nm^3. Total particulate escaping the scrubber was 0.05 kg/Mw-hr, substantially less than the NSPS requirement of 0.45 kg/Mw-hr for all furnace emissions.

Organics

Given in Table 59 are details of the organics at various points in the furnace B-2 primary emission control system. The same consideration applies as described under particulates. The calculated concentration of organic matter generated by the furnace and remaining in the scrubbed gas was 283.7 mg/Nm^3 or 2.55 kg/hr (injected kerosene subtracted out. Because of inaccuracy in the kerosene flow rate determination, the assumption was made for this calculation only that all TCO components trapped by the SASS train were due to injected kerosene.) This value is 14 percent greater than the concentration of particulate emissions. The scrubber captured an additional 74.2 kg organic/hr or 96.7 percent of the total organics going to the control system. Thus, the total organic entering the scrubbers was 8530 mg/Nm^3 or 76.7 kg/hr (1.60 kg/Mw-hr).

Level 1 Organic Analysis

The SASS train catch was analyzed for organic compound categorization as follows. The particulate catch, including solids trapped in the probe, was combined and extracted, TCO and GRAV determined, the extract fractionated by LC and TCO, GRAV and IR run on all fractions. LC fractions 2 and 3 combined were analyzed by LRMS. The aqueous condensate (115 mL) was extracted and the extract plus the module rinse was used to extract the XAD-2 resin. A TCO and GRAV was determined, LC fractionation done and TCO, GRAV and IR done on each fraction. An LRMS was done on LC fractions 2 and 3 combined. Kerosene, which was injected to the gas blowers, was analyzed for TCO and GRAV and fractionated

TABLE 59. ORGANICS, FURNACE B-2

Organics not captured by the scrubbers

Sample Point - Bypass stack after venturi scrubbers.

Volume of Gas Sampled: 14.4018 NM^3

Sample Type	Weight Collected, mg	Concentration mg/NM^3	Kg^a per Hour	Kg per MW-hr	Kg per Mg Alloy
Probe and Filter	1,366	94.85	0.85 (0.22)	0.018 (0.0044)	0.09 (0.02)
Organic Module	10,420	723.52	6.5 (1.63)	0.14 (0.03)	0.67 (0.17)
Injected Kerosene	(all tco)	534.65	4.8 (1.2)	0.10 (0.03)	0.49 (0.12)
Net Organic		283.72	2.55 (0.64)	0.05 (0.01)	0.26 (0.07)

Organics captured by the scrubbers

Sample Point - At inlet to venturi and at scrubber discharge clarifier lift station.

Sample Type	Weight Solids Collected, mg	Concentration mg/L	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Scrubber Inlet	14	6.6	0.89	0.019	0.09
Scrubber Discharge	1102.0	551.0	75.1	1.56	7.7
Net Scrubber Organics		544.4	74.2	1.55	7.6
Total Organics going to the Primary Control System			76.7	1.60	7.89
% Scrubber Efficiency			96.67		

[a] Scrubber exhaust gas is split, one-fourth goes to a bypass flare, three-fourths to gas combustion equipment for other process uses. Numbers in parentheses are the amounts actually exhausted to the environ- (not counting destruction by the flare).

by LC. TCO and GRAV were done on each fraction. The sample was 100 percent TCO.

Scrubber feed and discharge waters were filtered for suspended solids determination and each phase separately extracted and TCO and GRAV determined. Only the scrubber discharge sample was subjected to LC fractionation and further analysis as above. LRMS analysis was performed on LC fractions 2 and 3 separately.

The data obtained are summarized in Tables 60-63. (No attempt was made to eliminate contribution of injected kerosene.) Of the organic matter captured by the SASS train, 66.6 percent (88.4 percent including the kerosene) was found in the organic module. All of the organic found in the probe and filter solids before LC fractionation was GRAV (high boiling point). GRAV material accounted for 100 percent (26 percent when the kerosene is included) of the organic found in the organic module before LC fractionation. IR and LRMS spectra indicate the organic captured by the SASS train is predominately aliphatic and aromatic hydrocarbons. The concentrations of aromatic hydrocarbons, particularly fused aromatics (PNAs) is quite high and could exceed DMEG values if destruction by the flare does not occur. The LRMS spectra for LC fractions 2 and 3 of the SASS particulates show strong evidence of fused aromatics with molecular weights greater than 216. Significant intensities (related to concentration) were found at masses 252, 266, 276, 292, and 302 which suggest the presence of the known carcinogens benzo(a)pyrene, dibenzofluorene, indeno(1,2,3-cd)pyrene, methyl dibenzanthracene, and dibenzochrysene isomers, respectively. No evidence of carcinogenic compounds was found in the SASS organic module. However, this may be due to the fact that the fractions analyzed were predominately TCO. The GRAV component, which usually contains most carcinogenic PNAs, being in low concentration, would have been assigned low relative intensities and, thus, not be reported.

The data for the organics found in the scrubber discharge water are summarized in Table 63. The organic in the scrubber water was 83 percent GRAV material. Significantly, the data indicate that as much as 30 mg/L of this material may be fused aromatics with molecular weights above 216. The LRMS indicates significant concentrations at masses 228, 252, 266, 276, and 302 which suggest the presence of the known carcinogens chrysene, benzo(a)pyrene,

TABLE 60. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B2-PART

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/m^3	11.8	3.5	30.5	11.9	2.3	7.1	0.4	67.4
TCO, mg/m^3	11.8	0.9	2.2	1.5	0	0	0	16.4
GRAV, mg/m^3	0	2.6	28.3	10.4	2.3	7.1	0.4	51.0

Category Assigned Intensity - $mg/(m^3)$

Aliphatic Hydrocarbons	100/5.9	-	-	-	QNS*	QNS*	-	5.9
Halogenated Aliphatics	100/5.9	100/2.9	-	-			-	8.8
Aromatic Hydrocarbons	-	10/0.29	100/9.8	-			-	10.09
Halogenated Aromatics	-	10/0.29	100/9.8	-			-	10.09
Silicones	-	-	10/0.98	100/3.2			-	4.18
Heterocyclic O Compounds	-	-	100/9.8	10/0.32			-	1.3
Nitroaromatics	-	-	-	10/0.32			-	0.32
Ethers	-	-	-	100/3.2			-	3.2
Aldehydes	-	-	-	10/0.32			-	0.32
Phosphates	-	-	-	10/0.32			-	0.32
Nitriles	-	-	-	10/0.32			-	0.32
Heterocyclic N Compounds	-	-	-	10/0.32			10/0.014	0.334
Heterocyclic S Compounds	-	-	-	10/0.32			-	0.32
Alcohols	-	-	-	-			10/0.014	0.014
Phenols	-	-	-	-			10/0.014	0.014
Ketones	-	-	-	100/3.2**			100/0.14	3.34

(Continued)

*Quantity Not Sufficient. **Possible Contamination.

TABLE 60. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B2-PART

Category	Assigned Intensity - mg/(m^3)							
Amines	-	-	-	-	QNS*	QNS*	10/0.014	0.014
Alkyl S Compounds	-	-	-	-			10/0.014	0.014
Sulfuric Acids	-	-	-	-			10/0.014	0.014
Sulfoxides	-	-	-	-			100/0.14	0.14
Amides	-	-	-	-			10/0.014	0.014
Carboxylic Acids	-	-	-	-			10/0.014	0.014
Esters	-	-	-	-			10/0.014	0.014

*Quantity Not Sufficient.

TABLE 61. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B2-X

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/m^3	699.0	159.3	84.0	14.6	9.0	4.6	1.4	971.9
TCO, mg/m^3	699.0	153.2	81.7	12.7	7.6	0.5	0	954.7
GRAV, mg/m^3	0	6.1	2.3	1.9	1.4	4.1	1.4	17.2

Category	Assigned Intensity - mg/(m^3)							
Aliphatic Hydrocarbons	100/174.8	-	-	-	QNS*	QNS*	QNS*	174.8
Halogenated Aliphatics	100/174.8	100/11.1	-	-				185.9
Aromatic Hydrocarbons	100/174.8**	100/11.1	100/27.1	-				213.0
Halogenated Aromatics	100/174.8**	100/11.1	100/27.1	-				213.0
Silicones	-	100/11.1	10/2.71	10/0.52				14.33
Heterocyclic O Compounds	-	-	100/27.1	10/0.52				27.62
Nitroaromatics	-	-	-	10/0.52				0.52
Ethers	-	-	-	100/5.2				5.2
Aldehydes	-	-	-	10/0.52				0.52
Phosphates	-	-	-	10/0.52				0.52
Nitriles	-	-	-	10/0.52				0.52
Heterocyclic N Compounds	-	-	-	10/0.52				0.52
Heterocyclic S Compounds	-	-	-	10/0.52				0.52
Alcohols	-	-	-	-				
Phenols	-	-	-	-				
Ketones	-	-	-	100/5.2**				5.2

(Continued)

*Quantity Not Sufficient. **Possible Contamination.

TABLE 61. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B2-X (Cont'd)

Category	Assigned Intensity - mg/(m^3)							
Amines	–	–	–	–	QNS*	QNS*	QNS*	
Alkyl S Compounds	–	–	–	–				
Sulfuric Acids	–	–	–	–				
Sulfoxides	–	–	–	–				
Amides	–	–	–	–				
Carboxylic Acids	–	–	–	–				
Esters	–	–	–	–				

*Quantity Not Sufficient.

TABLE 62. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B2-K

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/mL	725.0	56.4	11.4	9.4	2.4	0.2	0	804.8
TCO, mg/mL	725.0	56.4	11.4	9.4	2.4	0.2	0	804.8
GRAV, mg/mL	0	0	0	0	0	0	0	0

Category	Assigned Intensity - mg							
Aliphatic Hydrocarbons	100/659	QNS*	QNS*	QNS*	QNS*	QNS*	-	659
Halogenated Aliphatics	10/65.9						-	65.9
Aromatic Hydrocarbons	-						-	
Halogenated Aromatics	-						-	
Silicones	-						-	
Heterocyclic O Compounds	-						-	
Nitroaromatics	-						-	
Ethers	-						-	
Aldehydes	-						-	
Phosphates	-						-	
Nitriles	-						-	
Heterocyclic N Compounds	-						-	
Heterocyclic S Compounds	-						-	
Alcohols	-						-	
Phenols	-						-	
Ketones	-						-	

(Continued)

*Quantity Not Sufficient.

TABLE 62. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B2-K (Cont'd)

Category		Assigned Intensity - mg						
Amines	-	QNS[*]	QNS[*]	QNS[*]	QNS[*]	QNS[*]		
Alkyl S Compounds	-							
Sulfuric Acids	-							
Sulfoxides	-							
Amides	-							
Carboxylic Acids	-							
Esters	-							

[*] Quantity Not Sufficient.

TABLE 63. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B2-SWD

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/L	133.5	133.5	122.5	75.0	30.0	62.5	8.0	565.0
TCO, mg/L	25.0	8.5	1.5	6.0	11.0	19.5	0	71.5
GRAV, mg/L	108.5	125.0	121.0	69.0	19.0	43.0	8.0	493.5

Category	Assigned Intensity - mg/L							
Aliphatic Hydrocarbons	100/66.75	-	-	-	-	QNS*	QNS*	66.75
Halogenated Aliphatics	100/66.75	100/43.1	-	-	-			109.85
Aromatic Hydrocarbons	-	100/43.1	100/29.9	-	-			73.0
Halogenated Aromatics	-	100/43.1	100/29.9	-	-			73.0
Silicones	-	10/4.31	10/2.99	10/1.15	-			8.45
Heterocyclic O Compounds	-	-	100/29.9	100/11.5	-			41.4
Nitroaromatics	-	-	-	10/1.15	10/0.57			1.72
Ethers	-	-	-	100/11.5	100/5.7			17.2
Aldehydes	-	-	-	10/1.15	10/0.57			1.72
Phosphates	-	-	-	10/1.15	10/0.57			1.72
Nitriles	-	-	-	10/1.15	10/0.57			1.72
Heterocyclic N Compounds	-	-	-	100/11.5	100/5.7			17.2
Heterocyclic S Compounds	-	-	-	100/11.5	100.5.7			17.2
Alcohols	-	-	-	-	10/0.57			0.57
Phenols	-	-	-	-	10/0.57			0.57
Ketones	-	-	100/29.9**	100/11.5**	100/5.7			47.1

(Continued)

*Quantity Not Sufficient. **Possible Contamination.

TABLE 63. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B2-SWD (Cont'd)

Category	Assigned Intensity - mg/L							
Amines	-	-	-	-	10/0.57	QNS*	QNS*	0.57
Alkyl S Compounds	-	-	-	-	10/0.57			0.57
Sulfuric Acids	-	-	-	-	10/0.57			0.57
Sulfoxides	-	-	-	-	10/0.57			0.57
Amides	-	-	-	-	10/0.57			0.57
Carboxylic Acids	-	-	-	-	10/0.57			0.57
Esters	-	-	-	100/11.5**	10/0.57			12.07

*Quantity Not Sufficient. **Possible Contamination.

dibenzofluorene, indeno(1,2,3-cd)pyrene, and dibenzochrysene isomer, respectively.

In summary, the test results on furnace B-2 show that the scrubbers are effective for control of particulates generated and capture over 96 percent of the organics generated (primary control system only). The data also indicate that a significant amount of fused aromatic hydrocarbons are generated by the furnace. Analysis of this material indicates the possibility of substantial amounts of carcinogens. Although the scrubbers capture a large fraction of these materials, a significant concentration of potential carcinogens is indicated in the scrubbed gas.

12.2.8 Plant B Final Wastewater Discharge

All wastewater from the plant flows into about 20 acres of ponds where solids settle out and the clarified water is chlorinated. Solids are dredged out of the ponds as required and landfilled on company property. A grab sample of the final pond effluent, 7.57 M^3/min (2000 gpm), was taken the same day furnace B-2 was tested. The sample was filtered for suspended solids determination, extracted and subjected to LC, IR, TCO, GRAV, and LRMS analysis. The overall results for solids and organics are summarized in Table 64, and the Level 1 organic analysis is summarized in Table 65. There was no indication of fused ring aromatic compounds or carcinogenic compounds.

12.2.9 Plant B Summary

Testing was conducted at this plant to compare two furnaces of different design producing the same product (50 percent FeSi). Furnace B-1 is of open design which allows vigorous combustion of the furnace gases. Furnace B-2, a tightly sealed, mix-sealed type furnace, operates with essentially no combustion of the furnace gases. The results, Table 66, indicate that furnace B-1 more effectively destroys organic compounds. Also, since little fume was observed from the top cover of furnace B-2, the above indication is virtually certain.

Detailed analysis indicates carcinogenic compounds in all furnace streams sampled. Furnace B-1 seems to generate fewer types of carcinogenic compounds and a lower total mass of the compounds than does furnace B-2. Although furnace B-2 scrubbers capture a large fraction of the organics generated, a

TABLE 64. PLANT B FINAL EFFLUENT

Sample Point - Discharge from final pond (just upstream of final discharge sample point).

Total Plant Discharge Flow Rate: 7.571 m^3/min (2000 gpm)

Component	Weight Collected, mg	Concentration mg/L	Kg Emitted per Hour
Suspended Solids	9	2.3	1
Organics*	24	12	5.5

*Zero percent of the organic is adsorbed on the solids.

The organic is concentrated in LC fractions 3 and 6.

Only high molecular weight aliphatic compounds are indicated by IR and LRMS.

TABLE 65. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B-PE

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/L	0.2	0	1.9	1.05	0.35	2.95	0.35	6.8
TCO, mg/L	0.2	0	0	0	0	0.35	0	0.55
GRAV, mg/L	0	0	1.9	1.05	0.35	2.60	0.35	6.25

Category	Assigned Intensity - mg/L							
Aliphatic Hydrocarbons	QNS*	QNS*	-	-	-	-	-	
Halogenated Aliphatics			-	-	-	-	-	
Aromatic Hydrocarbons			10/0.08	-	-	-	-	0.08
Halogenated Aromatics			10/0.08	-	-	-	-	0.08
Silicones			10/0.08	100/0.22	-	-	-	0.30
Heterocyclic O Compounds			10/0.08	10/0.02	-	-	-	0.10
Nitroaromatics			-	10/0.02	10/0.01	-	-	0.03
Ethers			100/0.79**	100/0.22	100/0.1	-	-	1.11
Aldehydes			-	10/0.02	10/0.01	-	-	0.03
Phosphates			-	10/0.02	10/0.01	10/0.14	100/0.09	0.26
Nitriles			-	10/0.02	10/0.01	-	-	0.03
Heterocyclic N Compounds			-	10/0.02	10/0.01	10/0.14	10/0.009	0.179
Heterocyclic S Compounds			-	10/0.02	10/0.01	-	-	0.03
Alcohols			-	-	10/0.01	10/0.14	10/0.009	0.159
Phenols			-	-	10/0.01	10/0.14	10/0.009	0.159
Ketones			100/0.79**	100/0.22**	10/0.01	10/0.14	100/0.09	1.25

(Continued)

*Quantity Not Sufficient. **Possible Contamination.

TABLE 65. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. B-PE (Cont'd)

Category	Assigned Intensity - mg/L							
Amines	QNS*	QNS*	-	-	10/0.01	10/0.01	10/0.009	0.159
Alkyl S Compounds			-	-	10/0.01	10/0.14	10/0.009	0.159
Sulfuric Acids			-	-	10/0.01	10/0.14	10/0.009	0.159
Sulfoxides			-	-	10/0.01	100/1.4	10/0.009	0.159
Amides			-	-	10/0.01	10/0.14	10/0.009	0.159
Carboxylic Acids			-	-	10/0.01	10/0.14	10/0.009	0.159
Esters			-	100/0.22**	100/0.1	10/0.14	100/0.09	0.55

*Quantity Not Sufficient. **Possible Contamination

TABLE 66. DATA COMPARISON, FURNACES B-1 AND B-2

Furnace No.	Component	Remaining in Cleaned Gas kg/hr	Remaining in Cleaned Gas kg/Mw-hr	Remaining in Cleaned Gas kg/Mg Alloy	Total Generated[b] kg/hr	Total Generated[b] kg/Mw-hr	Total Generated[b] kg/Mg Alloy
B-1	Particulate				470.6	9.72	49.2
B-2	Particulate	2.24	0.05	0.23	447.7	9.3	46
B-1	Organic				11.96	0.25	1.25
B-2	Organic	2.55	0.05	0.26	76.7	1.60	7.89

[a] No data for furnace B-1 since baghouse collection efficiency not determined. Only 25 percent of stated value for furnace B-2 goes to the flare since the gas is used as fuel in another process (not typical for the industry). Some destruction of organics by the flare is expected.

[b] Sum of component in scrubber discharge gas and scrubber water for furnace B-2. It does not include secondary fumes from furnace B-2. Hood design for furnace B-1 essentially collects all of the furnace fumes.

significant amount may be present in the scrubbed gas. No evidence was found for carcinogenic organic compounds in the plant final wastewater discharge. This strongly suggests that the solids removed from the wastewater ponds and landfilled on plant property contain a significant amount of organic matter, including known carcinogens.

A major difference in the emission control systems, besides the gas combustion difference, is the volume of air that is collected and cleaned. Gas volume from furnace B-1 is 12,467 Nm^3/min (440,255 ft^3/min) while 150 Nm^3/min (5296 ft^3/min) is scrubbed by the primary emission control system of furnace B-2. (Secondary emission control system gas flow rate is about 2500 Nm^3/min (88,000 ft^3/min).) Fan horsepower requirements are 2800 for furnace B-1 and 1400 for furnace B-2 (1200 for secondary emission control and 200 for the CO blowers).

12.3 PLANT C TESTS

Sampling at Plant C was conducted to compare similar furnaces producing different products. Both furnaces are of mix-sealed design and, although not as tightly sealed as furnace B-2, allow limited undercover combustion of the furnace gases. The furnaces are of comparable size and the emission control systems are virtually identical. Furnace C-1 was producing 75 percent ferrosilicon (FeSi), a product containing 25 percent iron and 75 percent silicon. Furnace C-2 was producing 50 percent ferrosilicon, the same product type produced by furnaces B-1 and B-2. Both materials are major product lines of the ferroalloy industry.

12.3.1 Plant C General Description

This plant was shut down some months after testing was completed. The description applies to the plant at the time it was tested. The plant was started up in 1939 and currently has four mix-sealed furnaces. Three of the four furnaces at this plant were in operation making either 50 percent FeSi or 75 percent FeSi. A specialty grade ferroalloy (SMZ) is also made at the plant. The furnace numbers and furnace test numbers are not consistent, i.e., test C-1 and C-2 were not done on furnace numbers 1 and 2.

Furnace No. 1, a mix-sealed furnace of about 17 MVA produces 50 percent FeSi or 75 percent FeSi. Prebaked electrodes, 0.89 m (35 inches) O.D., are used.

Furnace No. 3, a mix-sealed furnace of about 17 MVA. Produces 50 percent FeSi. Prebaked electrodes, 0.89 m (35 inches) O.D., are used.

Furnace No. 4, a mix-sealed furnace of about 22 MVA. Was not operating due to economic conditions. It uses 1.02 m (40 inches) prebaked electrodes.

Furnace No. 5, a mix-sealed furnace of about 20 MVA. Produces 75 percent FeSi. Self-baking electrodes, 1.07 m (42 inches) are used.

The two fume collection ducts on each furnace cover pass down through the operating floor. The gas in each duct is cleaned in a Buffalo Forge scrubber of about 57 m^3/min (2,000 ACFM) capacity. The cleaned gaseous discharge from each scrubber goes to a separate flare stack.

The eight flare stacks at Plant C (two per furnace) all have igniters which spark periodically and ignite a natural gas pilot. Depending on the heating value of the flare gas at the time, the flare may or may not ignite. The unlit stack emissions vary from a grayish smoke to a pure white steam plume. The carbon monoxide content of the gases going to the flare was reported by plant personnel to average around 50 to 55 volume percent.

All the furnaces have secondary hooding to collect any fumes leaking from around the electrodes. The secondary hoods and the furnace taphole controls are ducted to a single baghouse.

The capture efficiency of the secondary hooding varied from furnace to furnace. One furnace, which was blowing much fume past the electrode seals, still appeared to have a capture efficiency of over 90 percent, while another furnace had a somewhat lower capture efficiency, about 80 percent.

Taphole particulate control consists of an approximately 1 meter (3 feet) square duct near the taphole and a hydraulically operated cylindrical "cap" which is positioned over the ladle during tapping to divert the fumes to the mentioned duct. The fumes collected by the tapping control hoods go to the baghouse together with collected fumes from the secondary control hoods. Casting at this plant is from ladles into square chills by overhead crane.

The baghouse is relatively new and incorporates improvements over earlier baghouses built by the company. It is designed to handle 18,400 m^3/min (650,000 ACFM). There are 13 compartments with 500-0.2 by 6.4 m (8 inches x 21 feet) Nomex bags per compartment. There are two 2,000 HP fans on the baghouse, but normally only one operates unless the plant is operating at full load making large amounts of 75 percent FeSi (75 percent FeSi generates more dust than 50 percent FeSi). The normal gas temperature is 66-93°C (150-200°F) at the baghouse.

Housekeeping around the baghouse was excellent. The dust collected in the baghouse is dumped into cement trucks, water is added, and the slurry is dumped into a pit dedicated for the service. The area is hosed down once per shift to clean up any dust spills.

The water discharge from the scrubbers is chlorinated (lime is added for pH control) and sent to settling pond No. 5. The settling pond is about 11 m (34 feet) deep and covers 13 acres. It is almost full after being in service 25 to 30 years.

The overflow from Pond No. 5 runs into a second settling pond of 17 acres which was constructed about seven years ago. Effluent is pumped from the second settling pond to a clarifier flocculator where lime and flocculant are added. The overflow from the clarifier flocculator is chlorinated and is collected in two small settling ponds (1 acre each) before mixing with all plant wastewater in a third pond. All wastewater is discharged over a single weir into a slough on the river. Land is available at the plant and a new settling pond may be constructed to replace Pond No. 5. All the scrubber water is once-through river water; there is no recirculation of scrubber water.

There is, in addition to the main settling ponds, a pair of ponds in series which are used to settle water from gravel washing. The incoming gravel is washed to remove fine sand which is settled in the first pond and reclaimed every year or two.

Raw materials storage (coke, ore, gravel and wood chips) is in the open, on concrete pads, between the plant and the settling ponds.

12.3.2 Furnace C-1 Description

Furnace C-1, Figure 7, is a mix-sealed furnace producing 75 % FeSi. The furnace was designed to operate at about 16 Mw. Power is supplied to the furnace through three 1.07 m (42 inches) diameter self-baking carbon electrodes arranged in typical delta formation. The furnace cover does not produce a tight gas seal. Air can be drawn into the furnace through openings at the doors (warped) and other areas around the cover. Air is probably also drawn into the furnace through the mix-seals, especially when the mix level is

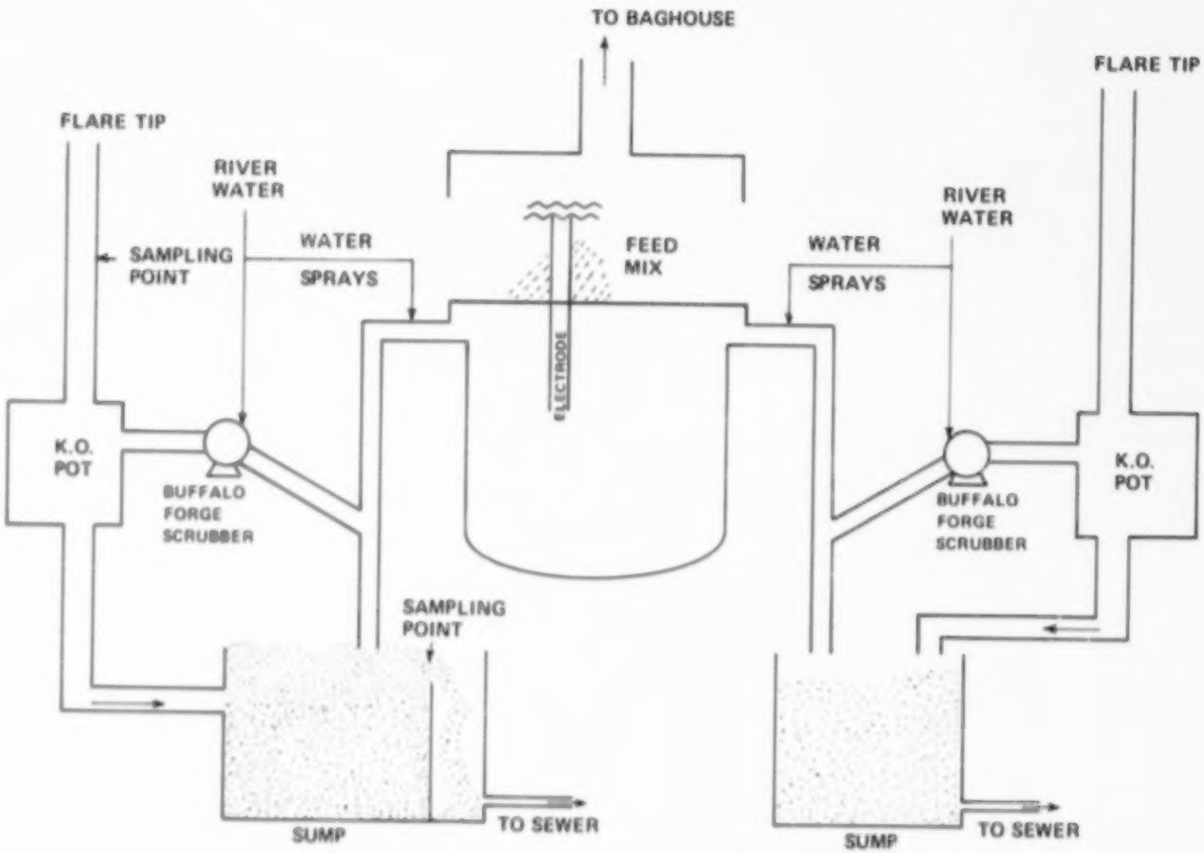
TO BAGHOUSE
FLARE TIP
FLARE TIP
RIVER WATER
RIVER WATER
SAMPLING POINT
WATER SPRAYS
FEED MIX
WATER SPRAYS
ELECTRODE
K.O. POT
BUFFALO FORGE SCRUBBER
BUFFALO FORGE SCRUBBER
K.O. POT
SAMPLING POINT
SUMP
TO SEWER
SUMP
TO SEWER

Figure 1. Emission control system, furnaces C-1 and C-2.

low. The inspirated air allows the furnace gas to be partially combusted under the furnace cover.

Raw materials (mix) are premixed and delivered to storage bins above the furnace in "trip" cars. Mix is fed to the furnace on an as needed basis through nine chutes (three for each electrode) onto the furnace cover and it provides a partial gas seal at the electrodes. Additional amounts of coal and stone (gravel) can be directly added onto the furnace cover if needed to stabilize operations.

Furnace controls are essentially all manual. Recording of operating data is also manual. It became obvious during the time spent at the plant that stability of operations depended heavily on individual operator skill.

The furnace is tapped (alloy withdrawn) at about 23 Mw-hr intervals. About 2.7 Mg (3 tons) of alloy are recovered from each tap. Slag is not produced by the furnace.

Fumes from the furnace cover (secondary fumes) are collected by a hood and are captured in a baghouse (secondary fumes and tapping fumes from all furnaces go to the same baghouse). Furnace gases are withdrawn from beneath the cover through two parallel scrubbing systems (50 percent of gas through each system) located 180° apart. Water is sprayed into the gas duct just as the gases leave the furnace. The cooled gases pass through a Buffalo Forge type scrubber (design 57 m^3/min - 2000 ACFM each) and a water knockout pot before entering the flare stack. Although the stacks are equipped with auto-igniters, the flares do not burn continuously.

Water flow rate to each scrubber is about 0.95 m^3/min (250 gpm). The scrubbers operate once-through (no recirculation). All collected and condensed water from each scrubber collects in a local sump before discharging to the plant sewer system.

12.3.3 Test Description, Furnace C-1

Samples were taken (see Figure 7 for location of sampling points) of the cleaned gases (scrubber discharge gas) from the primary emission control system, and of the scrubber feed and discharge waters. The sampling point for the gas sample was in the 50.8 cm (20 inches) internal diameter duct leading to the flare. The sample was collected using the complete SASS train (adapted so that nitrogen flushing of the system was possible before sampling and during filter changes).

Water samples were collected during the SASS test run. Eight liters (2 gallons) of scrubber feed water were taken from a tap near the furnace. Eight liters of scrubber discharge water were taken from the local sump for the scrubber and stack being tested. About one-third of each sample was taken at the end of each hour of SASS testing.

Since an "instantaneous" feed rate cannot be determined because mix is fed from storage bins, the furnace feed rate was determined by averaging the mix delivered in the 12-hour period before and during the test. Average furnace power was 15.5 Mw and average production of alloy was 1.91 Mg/hr (2.1 tons/hr). Given in Table 67 is the raw material feed recipe for furnace C-1. The product alloy averaged 74.5 percent silicon during the test period. A velocity traverse was made of the gas duct (through the same port to be used in the SASS test) prior to the test during a period when the furnace was not operating (the emission control system, however, was operating at normal levels). The SASS probe was inserted into the duct during this brief outage. After verifying that the furnace was operating properly, sampling was begun. Sampling was interrupted twice to make filter changes. A net sampling time of 216 minutes was obtained in the 300 minute sampling period. The test was terminated voluntarily.

12.3.4 Test Results, Furnace C-1

On-site Results

The velocity traverse data for the duct is shown in Table 68.

An Orsat analysis of the gas taken during the SASS test is shown in Table 69.

Data taken with the SASS train during the actual test is given in Table 70.

Particulates

Given in Table 71 are the amounts of particulate generated, captured by the scrubber, and escaping the scrubber of furnace C-1. It should be noted that these data apply only to particulate from the primary emission control system. Some fumes were observed escaping the furnace cover (through the mix-seals) but these were not judged to be substantial. These fumes, which

TABLE 67. RAW MATERIALS FEED FOR FURNACE C-1

15.5 Mw (1.91 Mg ALLOY/HR)

Component	kg per Trip	kg per Hour	kg per Mw-Hr	kg Consumed Per Mg of Alloy Produced
Si Ore				
Washed SOU Stone	907	3,297	213	1,731
Reducing Agent				
Quinwood N-Coal	289	1,052	68	552
Rosa P Coal	159	577	37	303
Fe Component				
A-1 Steel	141	511	33	269
Other				
Wood Chips	635	2,308	149	1,212
Electrode - No Data				
Total	2,131	7,745	501	4,066

TABLE 68. VELOCITY TRAVERSE, FURNACE C-1 STACK

Distance, cm	ΔP, mmHg	Distance, cm	ΔP, mmHg
1.0	0.54	32.8	0.60
3.3	0.54	33.0	0.56
6.1	0.54	41.9	0.52
8.9	0.58	44.7	0.49
12.7	0.60	47.5	0.45
18.0	0.62	49.8	0.37

Average ∇P = 0.53 mmHg   Temperature 51.7°C

Gas Velocity 594 m/min.

Flow Rate at Stack Conditions 120.4 m^3/min.

Flow Rate at Standard Conditions 93.6 m^3/min.

TABLE 69. ORSAT ANALYSIS, FURNACE C-1

Component	Percent by Volume[+]
CO_2	10.4
CO	28.2
O_2	1.4
Non-condensible	60.0

[+] Dry basis.

TABLE 70. SASS TEST DATA, FURNACE C-1

Date of Test	6/13/79	
Volume of Gas Sampled	19.749 Nm^3	(697.431 DSCF)
Stack Gas Temperature	68.3°C	(155°F)
Pressure, Absolute	75.3 cm Hg	(29.64 in Hg)
Dry Molecular Weight	29.72	
Wet Molecular Weight	27.08	
Moisture, percent	22.5	
Velocity	9.78 m/sec	(32.1 F/sec)
Flow Rate, each stack	78.24 Nm^3/min	(2,763 DSCFM)
	118.7 m^3/min	(4,193 ACFM)
Total Sampling Time	216 minutes	
SASS Flow Rate	0.0915 Nm^3/min	(3.23 DSCFM)
Percent Isokinetic	122	

[+] 20°C (68°F), 76.0 cm Hg (29.92 in Hg).

TABLE 71. PARTICULATES, FURNACE C-1

Particulate not captured by the scrubber

Sample Point - In stack after Buffalo Forge scrubber.

Volume of Gas Sampled: 19.749 NM^3

Sample Type	Weight Collected, mg	Concentration mg/NM^3	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Probe	1,893.0	95.85	0.90	0.058	0.47
10μ Cyclone	7,585.7	384.11	3.61	0.23	1.89
3μ Cyclone	707.5	35.83	0.34	0.022	0.18
1μ Cyclone	68.4	3.46	0.033	0.0021	0.017
<1μ Filters	6,040.0	305.8	2.87	0.185	1.50
Total	16,294.6	825.1	7.75	0.50	4.06

Particulate captured by the scrubber

Sample Point - Scrubber feed water and scrubber discharge sump weir.

Sample Type	Weight Solids Collected, mg	Concentration mg/L	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Scrubber Inlet	16	4.13	0.47	0.030	0.25
Scrubber Discharge	5,513	1668	189	12.2	99
Net Scrubber Solids		1664	189	12.2	99
Total Solid going to the Primary Control System			196.7	12.7	103
% Scrubber Efficiency, Solids			96.06		

sometimes burn as they leave the cover, are collected and captured in a baghouse which handles most secondary fumes in the plant. About 37 percent of the particulate captured by the SASS train was less than 1 micron in size. Over 46 percent was greater than 10 microns in size. There is a particularly dramatic variation in particle size noted in this sample which can also be seen in most other SASS samples taken. That is, the mass captured in each succeedingly smaller size fraction decreases dramatically, but the mass captured in the less than 1 micron size fraction is sharply larger (factor of about 90) than that captured in the 1-3 micron range. This does not appear to be related to scrubber design or efficiency for a particular size fraction since the same trend was found in particulates from furnace B-1, where gas was sampled before entering the control device.

Particulate concentration in the scrubbed gas was 825.1 mg/Nm^3 or 7.75 kg/hr (0.5 kg/Mw-hr) to be emitted to the atmosphere after passing through the flare. (Stack opacity appeared to exceed 40 percent most of the time.) The gas scrubber captured an additional 189 kg/hr of particulate matter or 96.1 percent of the primary dust generated. Total particulate concentration in the gas before the scrubber was, therefore, 20,950 mg/Nm^3 or 12.7 kg/Mw-hr. Emissions from the stacks (assuming no destruction of particulate by the flares) of 0.5 kg/Mw-hr would exceed NSPS (0.45 kg/Mw-hr) for all furnace emissions (primary and secondary).

Organics

Given in Table 72 are the amounts of the organic generated, captured by the scrubber, and escaping the scrubber of furnace C-1. The concentration of organic matter in the scrubbed gas (total SASS catch) going to the flares was 487.4 mg/Nm^3 or 4.58 kg/hr. (Inspection of the SASS train XAD-2 resin after the test indicated it was overloaded, thus, the above figures may actually be too low.) The amount of organics not captured by the scrubber (but possibly destroyed by the flares) are, therefore, about 59 percent as large as the amount of particulate not captured by the scrubber. The scrubbers captured 15 kg/hr or 76.7 percent of the organics going to the primary control system. The total organic matter entering the scrubbers was, therefore, 2,090 mg/Nm^3.

Over 95 percent of the organic captured by the SASS train was found in the organic module. Only 23.1 mg/Nm^3 was found on the particulate matter.

TABLE 72. ORGANICS, FURNACE C-1

Organics not captured by the scrubber

Sample Point - In stack after Buffalo Forge scrubber.

Volume of Gas Sampled: 19.749 NM^3

Sample Type	Weight Collected, mg	Concentration mg/NM^3	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Probe, Filter and Cyclones	456.2	23.10	0.217	0.014	0.11
Organic Module	9170	464.3	4.36	0.28	2.3
Total		487.4	4.58	0.30	2.4

Organics captured by the scrubber

Sample Point - Scrubber feed water and scrubber discharge sump weir.

Sample Type	Weight Solids Collected, mg	Concentration mg/L	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Scrubber Inlet	6.0	1.5	0.17	0.011	0.089
Scrubber Discharge	267.7	133.9	15.2	0.980	8.0
Net Scrubber Organics		132.4	15.0	0.97	7.9
Total Organics Going to the Primary Control System			19.6	1.27	10.3
% Scrubber Efficiency, Organics			76.66		

Organic content of the dust going to the flares was thus, about 2.8 percent. The organic content of the dust could be higher, however, since the SASS probe and cyclones were operated at about 204°C (400°F) (normal operating temperature for SASS system and used for all tests except B-2) substantially above the stack temperature of 68°C (155°F), and could have distilled the organics from the dust into the organic module. Organics found in the scrubber discharge water were 8 percent of the particulate captured. In this case some organic not associated with the dust may have been captured. Therefore, the actual organic content of particulate going to the flares is probably between 2.8 and 8.0 percent.

Level 1 Organic Analysis

The SASS train catch was analyzed for organic compound categorization as follows. The entire particulate catch (probe, cyclones, and filters) was extracted; analyzed for TCO and GRAV; fractionated by LC; TCO, GRAV, and IR run on each fraction; and LRMS run on LC fraction 2 and 3 combined. The aqueous condensate was extracted and the extract combined with the module rinse which was then used to extract the XAD-2 resin. The final extract was then analyzed for TCO, GRAV, fractionated by LC with subsequent analysis as for the particulates.

Scrubber feed and discharge waters were filtered to determine suspended solids, the solid and aqueous phases from each sample separately extracted. A TCO and GRAV was determined on each extract, the extracts for each sample combined and concentrated and analyzed for TCO and GRAV. No LC workup was performed on the scrubber feed water since the organic content was low. The scrubber discharge sample was analyzed by LC; TCO, GRAV and IR on each fraction; and LRMS on LC fractions 2 and 3, separately. The LC, IR, and LRMS results are contained in the appendices.

Summarized in Tables 73, 74, and 75 are the data obtained. Of the 23.1 mg/Nm^3 organic found in the SASS particulate catch, 97 percent was GRAV material. Of the 464.3 mg/Nm^3 captured by the organic module, 39 percent was GRAV material. Of the 133.9 mg/L organic in the scrubber water, 83 percent was GRAV material.

The data in Table 73 show that organics in the particulate catch contained appreciable quantities of aromatic hydrocarbons, halogenated aromatics and heterocyclic oxygen compounds with lesser amounts of nitrogen compounds,

TABLE 73 ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C1-PART

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/m^3	0.14	1.3	5.9	3.5	2.2	3.8	0.5	17.4
TCO, mg/m^3	0.14	0.07	0	0	0	0	0	0.21
GRAV, mg/m^3	0	1.21	5.9	3.5	2.2	3.8	0.5	17.19

Category Assigned Intensity - mg/(m^3)

Aliphatic Hydrocarbons	100/0.13	-	-	-	-	-	QNS*	0.13
Halogenated Aliphatics	10/0.01	100/0.4	-	-	-	-		0.41
Aromatic Hydrocarbons	-	100/0.4	100/1.9	-	-	-		2.3
Halogenated Aromatics	-	100/0.4	100/1.9	-	-	-		2.3
Silicones	-	10/0.04	10/0.19	10/0.08	-	-		0.31
Heterocyclic O Compounds	-	-	100/1.9	100/0.78	-	-		2.68
Nitroaromatics	-	-	-	10/0.08	10/0.03	-		0.11
Ethers	-	-	-	100/0.78	10/0.03	-		0.81
Aldehydes	-	-	-	10/0.08	10/0.03	-		0.11
Phosphates	-	-	-	10/0.08	10/0.03	10/0.1		0.21
Nitriles	-	-	-	10/0.08	10/0.03	-		0.11
Heterocyclic N Compounds	-	-	-	100/0.78	100/0.28	10/0.1		1.16
Heterocyclic S Compounds	-	-	-	100/0.78	100/0.28	-		1.06
Alcohols	-	-	-	-	100/0.28	10/0.1		0.38
Phenols	-	-	-	-	100/0.28	10/0.1		0.38
Ketones	-	-	-	-	100/0.28	100/1.0		1.28

(Continued)

[*] Quantity Not Sufficient.

TABLE 73 ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C1-PART (Cont'd)

Category	Assigned Intensity - mg/(m^3)							
Amines	-	-	-	-	100/0.28	10/0.1	QNS*	0.38
Alkyl S Compounds	-	-	-	-	10/0.03	10/0.1		0.13
Sulfuric Acids	-	-	-	-	10/0.03	10/0.1		0.13
Sulfoxides	-	-	-	-	10/0.03	10/0.1		0.13
Amides	-	-	-	-	10/0.03	100/1.0		1.03
Carboxylic Acids	-	-	-	-	10/0.03	10/0.1		0.13
Esters	-	-	-	-	100/0.28	100/1.0		1.28

*Quantity Not Sufficient.

TABLE 74. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C1-X

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/m^3	264.0	81.0	31.0	30.4	17.7	62.0	5.1	491.2
TCO, mg/m^3	262.7	59.5	5.70	19.0	8.9	19.0	0	374.7
GRAV, mg/m^3	1.3	21.5	25.3	11.4	8.8	43	5.1	116.5

Category Assigned Intensity - mg/(m^3)

Category	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Aliphatic Hydrocarbons	100/66.0	-		-	QNS*	-	QNS*	66.0
Halogenated Aliphatics	100/66.0	100/16.2		-		-		82.2
Aromatic Hydrocarbons	100/66.0**	100/16.2	100/28.0	-		-		110.2
Halogenated Aromatics	100/66.0**	100/16.2		-		-		82.2
Silicones	-	100/16.2		10/0.80		-		17.0
Heterocyclic O Compounds	-	-		10/0.80		-		0.8
Nitroaromatics	-	-		10/0.80		-		0.8
Ethers	-	-		100/8.0		-		8.0
Aldehydes	-	-		10/0.80		-		0.8
Phosphates	-	-		10/0.80		10/0.94		1.74
Nitriles	-	-		10/0.80		-		0.8
Heterocyclic N Compounds	-	-		10/0.80		100/9.4		10.2
Heterocyclic S Compounds	-	-		10/0.80		-		0.8
Alcohols	-	-		-		100/9.4		9.4
Phenols	-	-		-		100/9.4		9.4
Ketones	-	-		100/8.0**		10/0.94		8.94

(Continued)

*Quantity Not Sufficient. **Possible Contamination.

TABLE 74. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C1-X (Cont'd)

Category Assigned Intensity - mg/(m^3)

Amines	-	-	QNS*		QNS*	100/9.4	QNS*	9.4
Alkyl S Compounds	-	-				10/0.94		0.94
Sulfuric Acids	-	-				10/0.94		0.94
Sulfoxides	-	-				10/0.94		0.94
Amides	-	-				100/9.4		9.4
Carboxylic Acids	-	-				100/9.4		9.4
Esters	-	100/16.2**	10/3.0	100/8.0**		10/0.94		28.14

*Quantity Not Sufficient.

**Possible Contamination.

TABLE 75. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C1-SWD

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/L	23.0	25.8	47.8	22.8	15.6	15.3	2.9	153.2
TCO, mg/L	4.0	1.8	1.1	2.2	4.5	0.2	0	13.8
GRAV, mg/L	19.0	24.0	46.7	20.6	11.1	15.1	2.9	139.4

Category	Assigned Intensity - mg/L							
Aliphatic Hydrocarbons	100/5.8	--	--	--	--	--	--	5.8
Halogenated Aliphatics	100/5.8	100/8.3	--	--	--	--	--	14.1
Aromatic Hydrocarbons	100/5.8**	100/8.3	100/7.8	--	--	--	--	21.9
Halogenated Aromatics	100/5.8**	100/8.3	100/7.8	--	--	--	--	21.9
Silicones	--	10/0.83	10/0.78	10/0.35	--	--	--	1.96
Heterocyclic O Compounds	--	--	100/7.8	100/3.5	--	--	--	11.3
Nitroaromatics	--	--	--	10/0.35	10/0.35	--	--	0.7
Ethers	--	--	--	100/3.5	10/0.35	--	--	3.85
Aldehydes	--	--	100/7.8**	10/0.35	10/0.35	--	--	8.5
Phosphates	--	--	--	10/0.35	10/0.35	10/0.51	10/0.1	1.31
Nitriles	--	--	--	10/0.35	10/0.35	--	--	0.7
Heterocyclic N Compounds	--	--	--	100/3.5	100/3.5	100/5.1	100/1.0	13.1
Heterocyclic S Compounds	--	--	--	100/3.5	100/3.5	--	--	7.0
Alcohols	--	--	--	--	10/0.35	10/0.51	10/0.1	0.96
Phenols	--	--	--	--	10/0.35	10/0.51	10/0.1	0.96
Ketones	--	--	100/7.8**	100/3.5**	100/3.5	10/0.51	10/0.1	15.41

(Continued)

[*] Quantity Not Sufficient.

[**] Possible Contamination.

TABLE 75. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C1-SWD (Cont'd)

Category	Assigned Intensity - mg/L							
Amines	--	--	--	--	10/0.35	10/0.51	10/0.1	0.96
Alkyl S Compounds	--	--	--	--	10/0.35	10/0.51	10/0.1	0.96
Sulfuric Acids	--	--	--	--	10/0.35	10/0.51	10/0.1	0.96
Sulfoxides	--	--	--	--	10/0.35	10/0.51	10/0.1	0.96
Amides	--	--	--	--	10/0.35	100/5.1	100/1.0	6.45
Carboxylic Acids	--	--	--	--	10/0.35	10/0.51	10/0.1	0.96
Esters	--	--	100/7.8**	100/3.5**	10/0.35	10/0.51	10/0.1	12.26

*Quantity Not Sufficient. **Possible Contamination.

sulfur compounds, ketones, and esters. The LRMS indicates that the aromatic and halogenated aromatic hydrocarbons are predominately fused aromatics with molecular weights above 216. Major LRMS intensities (related to concentration) were found at masses 252 and 276, indicating possibly high concentrations of the known carcinogens benzo(a)pyrene and indeno(1,2,3-cd)pyrene, respectively. Minor LRMS intensities were found at masses 266 and 302 which could correspond to the carcinogens dibenzofluorene and dibenzochrysene isomer, respectively. A total of 15 different masses were found between mass 178 and 402 that correspond to fused aromatics.

The data in Table 74 show that the organic trapped in the SASS organic module contained high concentrations of many different compound categories. Most notable, however, are aliphatic and aromatic hydrocarbons. Aromatic hydrocarbon levels (192.4 mg/Nm^3) would be very high if emitted to the atmosphere. However, some flaring of this gas does occur and is expected to destroy some of the organics.

The LRMS analysis indicates that most of the aromatic hydrocarbons trapped in the organic module are fused aromatics with molecular weights above 216. Ten different masses indicating fused aromatics ranging from mass 152 to 376 were found. Major intensities were found at masses 252 and 276, which indicate possibly high concentrations of the carcinogens benzo(a)pyrene and indeno(1,2,3-cd)pyrene.

The data in Table 75 show that the organic content of the scrubber water is distributed among many compound categories. Aromatic hydrocarbons (including halogenated types) are the largest categories, totalling 43.8 mg/L.

The LRMS analysis of the scrubber water sample fractions shows 12 different masses (in the 178-326 Mw range) associated with fused aromatic hydrocarbon. Major intensities were found at masses 252, 266, and 276 which indicate the possible presence of significant amounts of the carcinogens benzo(a)pyrene, dibenzofluorene, and indeno(1,2,3-cd)pyrene, respectively. Minor peaks were found at masses 228, 202, and 302 indicating the possible presence of the carcinogens chrysene, methyl dibenzanthracene, and dibenzochrysene isomer, respectively.

12.3.5 Furnace C-2 Description

Furnace C-2, a mix-sealed furnace, is designed to operate at about 17 MVA. Prebaked carbon electrodes, three in triangular formation, with diameters of 0.89 m (35 inches) are used. The product made in the furnace is 50 percent FeSi. Raw material feed mechanisms, emission control systems, and general operation of the furnace are virtually identical to that for furnace C-1.

12.3.6 Test Description, Furnace C-2

Samples were taken from the same locations as sampled on furnace C-1 (see Figure 7). The SASS train was used to sample the cleaned gas (scrubber discharge) from the primary emission control system. A velocity traverse of the 50.8 cm (20 inches) duct was made prior to the SASS test (furnace off but emission control systems operating normally). An 8 liter (2 gallons) sample of the scrubber discharge water was taken (at the scrubber local sump) during the SASS test, approximately one-third collected at the end of each hour of testing. The test was voluntarily terminated after three hours. Total sampling time was 139 minutes.

Raw material consumption was determined by averaging the "trip" weights in the eight-hour shift preceding the test. Details of the feed mix are given in Table 76. Operating at 16.8 Mw, the furnace produces 2.72 Mg (3.0 tons) of alloy per operating hour. No slag is produced. A typical product analysis shows: 50.5 percent Si, 49.4 percent Fe, 0.1 percent Al.

During the SASS test, the furnace was operating at 16.8 Mw. Water flow to each scrubbers was 0.95 m^3/min (250 gpm).

12.3.7 Test Results, Furnace C-2

On-site Results

The velocity traverse data for the duct is shown in Table 77.

TABLE 76. RAW MATERIAL CONSUMPTION FOR FURNACE C-2

16.8 Mw (2.72 Mg ALLOY/HR)

Component	kg per Trip	kg per Hour	kg per Mw-Hr	kg Consumed Per Mg of Alloy Produced
Si Components				
Washed Southern Stone	1,089	3,429	204	1,260
Reducing Agents				
Petroleum Coke	45	134	9	53
Rosa Nut Coal	302	950	57	349
Rosa Pea Coal	239	753	45	276
Fe Component				
A-1 Steel	615	1,936	115	712
Other				
Wood Chips	227	714	43	262
Electrode - No Data				
Total	2,516	7,925	472	2,912

TABLE 77. VELOCITY TRAVERSE, FURNACE C-2 STACK

Distance, cm	ΔP, mmHg	Distance, cm	ΔP, mmHg
1.0	0.56	32.8	0.45
3.3	0.65	33.0	0.54
6.1	0.65	41.9	0.45
8.9	0.56	44.7	0.56
12.7	0.52	47.5	0.34
18.0	0.47	49.8	0.49

Average ΔP = 0.52 mmHg Temperature 41.7°C

Gas Velocity 567 m/min.

Flow Rate at Stack Conditions 115.4 m^3/min.

Flow Rate at Standard Conditions 98.5 m^3/min.

An Orsat analysis of the gas taken during the SASS test is shown in Table 78.

TABLE 78. ORSAT ANALYSIS, FURNACE C-2

Component	Percent by Volume+
CO_2	13.0
CO	24.5
O_2	0.0
Non-condensibles	62.5

+Dry basis.

Data taken with the SASS train during the actual test is given in Table 79.

TABLE 79. SASS TEST DATA, FURNACE C-2

Date of Test	6/19/79	
Volume of Gas Sampled	11.944 Nm^{3+}	(421.779 DSCF)
Stack Gas Temperature	50.6°C	(123°F)
Pressure, Absolute	75.7 cm Hg	(29.82 in Hg)
Dry Molecular Weight	30.08	
Wet Molecular Weight	28.51	
Moisture, Percent	13.0	
Velocity	9.11 m/sec	(29.9 F/sec)
Flow Rate, Each Stack	86.99 Nm^3/min	(3072 DSCFM)
	110.80 m^3/min	(3913 ACFM)
Total Sampling Time	139.0 minutes	
SASS Flow Rate	0.0859 Nm^3/min	(3.03 DSCFM)
Percent Isokinetic	104.8	

+20°C (68°F), 76.0 cm Hg (29.92 in Hg)

Particulates

Given in Table 80 are the amounts of particulate generated, captured by the scrubber, and escaping the scrubber of furnace C-2. It should be noted that these data apply only to particulates from the primary emission control system. Some fumes were observed escaping the furnace cover (through the mix seals) and at times were quite substantial. These fumes, which sometimes are burning, are collected and captured in a baghouse which handles most secondary fumes in the plant. About 32 percent of the particulate matter captured by the SASS train was less than 1 micron in size. Over 28 percent of the particulate matter was captured in the >10 micron size fraction cyclone. Particulate trapped in the >10 micron cyclone and probe accounted for 67 percent of the particulate captured. Less than one percent of the particulate matter was found in the 1-10 micron size range.

TABLE 80. PARTICULATES, FURNACE C-2

Particulate not captured by the scrubbers

Sample Point - In stack after Buffalo Forge scrubber.

Volume of Gas Sampled: 11.944 NM^3

Sample Type	Weight Collected, mg	Concentration mg/NM^3	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Probe	5,792.2	484.95	5.06	0.30	1.86
10μ Cyclone	4,191.8	350.95	3.66	0.22	1.34
3μ Cyclone	59.8	5.01	0.052	0.0031	0.019
1μ Cyclone	51.5	4.31	0.045	0.0027	0.016
<1μ Filter	4,733.8	396.33	4.14	0.25	1.52
Total	14,829.1	1241.55	12.96	0.77	4.75

Particulate captured by the scrubber

Sample Point - Scrubber inlet and scrubber discharge sump weir.

Sample Type	Weight Solids Collected, mg	Concentration mg/L	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Scrubber Inlet	16	4.1	0.47	0.030	0.17
Scrubber Discharge	6,023	1544	175.4	10.4	64.3
Net Scrubber Solids		1540	174.9	10.41	64.12
Total Solids going to the Primary Control System			187.9	11.2	68.9
% Scrubber Efficiency, Solids			93.10		

Particulate concentration in the scrubbed gas was 1241.6 mg/Nm^3 or 12.96 kg/hr (0.77 kg/Mw-hr) going to the flare. (Stack opacity appeared to exceed 40 percent most of the time.) The gas scrubbers captured an additional 174.9 kg/hr of particulate matter or 93 percent of the primary dust generated. Total particulate concentration in the gas before the scrubber was, therefore, 18,000 mg/Nm^3 or 11.2 kg/Mw-hr. Emissions from the stacks, assuming no destruction of particulate by the flares (0.77 kg/Mw-hr), would exceed NSPS (0.45 kg/Mw-hr) for all furnace emissions (primary and secondary).

Organics

Given in Table 8 are the amounts of organic generated, captured by the scrubbers, and escaping the scrubbers of furnace C-2. The concentration of organic matter in the scrubbed gas (total SASS catch) going to the flares was 195.6 mg/Nm^3 or 2.04 kg/hr. The amount of organic escaping the scrubbers is, therefore, about 15.8 percent as large as the amount of particulate escaping the scrubbers. The scrubbers captured 7.9 kg/hr or 79.5 percent of the total organics going to the primary emission control system. The total organic matter entering the scrubber was, therefore, 950 mg/Nm^3 or 0.59 kg/Mw-hr.

About 88 percent of the organic captured by the SASS train was found in the organic module. Only 23.8 mg/Nm^3 was found on the particulate matter. Organic content of the dust going to the flares was, therefore, about 2 percent. The organic content of the dust could be higher, however, since the SASS probe and cyclones operated at 204°C (400°F), substantially above the stack temperature of 50.6°C (123°F). Organics found in the scrubber discharge water were 4.5 percent of the particulate captured. Recognizing that not all of the organic captured by the scrubbers was associated with the particulate captured, the actual organic content of particulate going to the flares is probably between 2 and 4.5 percent. Some destruction of this organic material would occur when the gas was flared.

Level 1 Organic Analysis

The SASS train catch was analyzed for organic compound categorization as follows. The entire particulate catch (probe, cyclones, and filters) was combined and extracted; analyzed for TCO and GRAV; fractionated by LC; TCO, GRAV, and IR run on all fractions; and LRMS run on LC fractions 2 and 3,

TABLE 81. ORGANICS, FURNACE C-2

Organics not captured by the scrubbers

Sample Point - In stack after Buffalo Forge scrubber.
Volume of Gas Sampled: 11.944 NM^3

Sample Type	Weight Collected, mg	Concentration mg/NM^3	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Probe, Filter and Cyclones	284.7	23.84	0.25	0.015	0.091
Organic Module	2052	171.8	1.79	0.11	0.66
Total		195.6	2.04	0.12	0.75

Organics captured by the scrubbers

Sample Point - Scrubber feed water and scrubber discharge sump weir.

Sample Type	Weight Solids Collected, mg	Concentration mg/L	Kg per Hour	Kg per MW-hr	Kg per Mg Alloy
Scrubber Inlet	6.0	1.5	0.17	0.010	0.062
Scrubber Discharge	142.3	71.1	8.07	0.48	2.96
Net Scrubber Organics		69.6	7.90	0.470	2.90
Total Organics going to the Primary Control System			9.95	0.59	3.65
% Scrubber Efficiency, Organics			79.47		

separately. The aqueous condensate was extracted and the extract combined with the module rinse which was used to extract the XAD-2 resin. The extract was then analyzed as above, except that an LRMS was run on LC fractions 2 and 3 combined. The scrubber water discharge sample was filtered to determine suspended solids and the solid and liquid phases separately extracted. These extracts were then combined and concentrated. Analysis procedure was the same as above except that an LRMS was run only on LC fraction 3. The LC, IR, and LRMS data are in the appendices.

Summarized in Tables 82, 83, and 84 are the data obtained. Of the 23.8 mg/Nm^3 organic found in the particulate catch, 98 percent was GRAV material. GRAV material accounted for 73 percent of the 171.8 mg/Nm^3 organic material found in the organic module. Of the 71.1 mg/L found in the scrubber discharge water 94 percent was GRAV material.

The data in Table 82 show that the organics in the SASS particulate catch are predominately aromatic and halogenated aromatic hydrocarbons. Lesser amounts of aliphatic and heterocyclic oxygen compounds were found. The LRMS analysis of LC fraction 2 indicates that organics in this fraction are predominately fused aromatics with molecular weights less than 216. A minor LRMS peak was found at mass 228 which could be the carcinogen chrysene. The LRMS analysis of LC fraction 3 indicates the fraction is predominately fused aromatics with molecular weights above 216. Major LRMS intensities (related to concentration) were found at masses 252, 276, and 302, which indicate the possible presence of significant amounts of the carcinogens benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and dibenzochrysene isomer, respectively. A minor peak was also found at mass 228 which could be chrysene. A total of 13 different masses were found between mass 178 and 376 that correspond to fused aromatics.

Table 83 shows that the organic trapped in the SASS organic module had high concentrations of aliphatic and aromatic hydrocarbons with lesser amounts of most other compound categories. Aromatic hydrocarbon levels (294.46 mg/Nm^3, would be quite high if emitted to the atmosphere. However, some flaring of this gas does occur and is expected to destroy some of the organics.

The LRMS analysis of the SASS organic module LC fractions 2 and 3 combined indicates the material is predominately fused aromatics with molecular weights above 216. Major LRMS intensities were found at masses 252 and 276

TABLE 82. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C2-PART

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/m^3	2.3	2.1	8.0	4.3	2.5	0.9	0.2	20.3
TCO, mg/m^3	0.3	--	0	0.03	0.3	0	0	0.6
GRAV, mg/m^3	2.0	2.1	8.0	4.27	2.2	0.9	0.2	19.7

Category	Assigned Intensity - mg/(m^3)							
Aliphatic Hydrocarbons	100/0.58			QNS*	QNS*	QNS*	QNS*	0.58
Halogenated Aliphatics	100/0.58		--					0.58
Aromatic Hydrocarbons	100/0.58**	100/2.1	100/2.58					5.24
Halogenated Aromatics	100/0.58**		100/2.58					3.16
Silicones			10/0.258					0.258
Heterocyclic O Compounds			100/2.58					2.58
Nitroaromatics			--					
Ethers			--					
Aldehydes			--					
Phosphates			--					
Nitriles			--					
Heterocyclic N Compounds			--					
Heterocyclic S Compounds			--					
Alcohols			--					
Phenols			--					
Ketones			--					

(Continued)

*Quantity Not Sufficient. **Possible Contamination.

TABLE 82 ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C2-PART (Cont'd)

Category Assigned Intensity - mg/(m^3)

Amines	--	QNS*	--	QNS*	QNS*	QNS*	QNS*	
Alkyl S Compounds	--		--					
Sulfuric Acids	--		--					
Sulfoxides	--		--					
Amides	--		--					
Carboxylic Acids	--		--					
Esters	--		--					

*Quantity Not Sufficient.

TABLE 83. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C2-X

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/m^3	291.6	53.7	8.0	3.8	1.4	4.5	2.1	365.3
TCO, mg/m^3	284.7	36.3	2.4	1.0	0	0.4	0	324.8
GRAV, mg/m^3	6.9	17.4	5.6	2.8	1.4	4.1	2.1	40.5

Category	Assigned Intensity - $mg/(m^3)$							
Aliphatic Hydrocarbons	10/24.3	--	--	--	QNS*	--	QNS*	24.3
Halogenated Aliphatics	10/24.3	10/2.44	--	--		--		26.74
Aromatic Hydrocarbons	100/243**	100/24.4	100/1.33	--		--		268.73
Halogenated Aromatics	--	100/24.4	100/1.33	--		--		25.73
Silicones	--	10/2.44	100/1.33	100/0.81		--		4.58
Heterocyclic O Compounds	--	--	100/1.33	10/0.081		--		1.411
Nitroaromatics	--	--	--	10/0.081		--		0.081
Ethers	--	--	--	100/0.81		--		0.081
Aldehydes	--	--	--	10/0.081		--		0.081
Phosphates	--	--	--	10/0.081		10/0.15		0.231
Nitriles	--	--	--	10/0.081		--		0.081
Heterocyclic N Compounds	--	--	--	10/0.081		10/0.15		0.231
Heterocyclic S Compounds	--	--	--	10/0.081		--		0.081
Alcohols	--	--	--	--		10/0.15		0.15
Phenols	--	--	--	--		10/0.15		0.15
Ketones	--	--	100/1.33**	100/0.81**		100/1.5		3.64

(Continued)

*Quantity Not Sufficient. **Possible Contamination.

TABLE 83. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C2-X (Cont'd)

Category	Assigned Intensity - mg/(m^3)							
Amines	--	--	--	--	QNS[*]	10/0.15	QNS[*]	0.15
Alkyl S Compounds	--	--	--	--		10/0.15		0.15
Sulfuric Acids	--	--	--	--		10/0.15		0.15
Sulfoxides	--	--	--	--		10/0.15		0.15
Amides	--	--	--	--		10/0.15		0.15
Carboxylic Acids	--	--	--	--		10/0.15		0.15
Esters	--	--	100/1.33[**]	100/0.81[**]		100/1.5		3.64

[*] Quantity Not Sufficient. [**] Possible Contamination.

TABLE 84. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C2-SWD

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/L	1.4	1.7	49.5	11.8	4.7	1.5	2.9	73.5
TCO, mg/L	0.4	0.8	3.0	0	0.6	0	0	4.8
GRAV, mg/L	1.0	0.9	46.5	11.8	4.1	1.5	2.9	68.7

Category	Assigned Intensity - mg/L							
Aliphatic Hydrocarbons	QNS*	--	--	--	--	QNS*	QNS*	0
Halogenated Aliphatics		100/0.4	--	--	--			0.4
Aromatic Hydrocarbons		100/0.4	100/9.7	--	--			10.1
Halogenated Aromatics		100/0.4	100/9.7	--	--			10.1
Silicones		10/0.04	10/0.97	10/0.26	--			1.27
Heterocyclic O Compounds		--	100/9.7	100/2.6	--			1.23
Nitroaromatics		--	--	10/0.26	10/0.06			0.32
Ethers		100/0.4**	--	100/2.6	10/0.06			3.06
Aldehydes		--	--	10/0.26	10/0.06			0.32
Phosphates		--	--	10/0.26	10/0.06			0.32
Nitriles		--	--	10/0.26	100/0.59			0.85
Heterocyclic N Compounds		--	--	100/2.6	100/0.59			3.19
Heterocyclic S Compounds		--	--	100/2.6	100/0.59			3.19
Alcohols		--	--	--	100/0.59			0.59
Phenols		--	--	--	10/0.06			0.06
Ketones		--	100/9.7**	--	100/0.59			10.29

(Continued)

*Quantity Not Sufficient. **Possible Contamination.

TABLE 84. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C2-SWD (Cont'd)

Category	Assigned Intensity - mg/L							
Amines	QNS*	--	--	--	100/0.59	QNS*	QNS*	0.59
Alkyl S Compounds		--	--	--	10/0.06			0.06
Sulfuric Acids		--	--	--	10/0.06			0.06
Sulfoxides		--	--	--	10/0.06			0.06
Amides		--	--	--	10/0.06			0.06
Carboxylic Acids		--	--	--	10/0.06			0.06
Esters		--	100/9.7**	--	100/0.59			10.29

*Quantity Not Sufficient. **Possible Contamination.

which indicates the possible presence of the carcinogens benzo(a)pyrene and indeno(1,2,3-cd)-pyrene, respectively. Minor intensities were found at masses 228, 266, and 302 which could be the carcinogens chrysene, dibenzofluorene, and dibenzochrysene isomer, respectively. A total of 12 different masses in the range 178-350 were found indicating fused aromatic hydrocarbons.

The data in Table 84 show that the organic compounds in the scrubber water are distributed among many compound categories. Aromatic hydrocarbons, including halogenated types, are the largest categories, totalling 20.2 mg/L. Other significant categories are ether, heterocyclic nitrogen and sulfur compounds, ketones, and esters.

The LRMS analysis of the scrubber water LC fraction 3 indicates this fraction is predominately fused aromatics with molecular weights above 216. Major intensities were found at masses 252, 276, and 302 which indicates the possible presence of significant amounts of benzo(a)pyrene, indeno(1,2,3-cd)-pyrene, and dibenzochrysene isomer, respectively. Minor intensities were also found at masses 228 and 266, indicating the possible presence of the carcinogens chrysene and dibenzofluorene, respectively. A total of 15 different masses in the range 178-376 were found indicating the presence of fused aromatics.

GC-MS Analysis

Gas chromatography-mass spectrographic (GC-MS) or direct inlet probe analyses were run on two of the samples from furnace C-2 for exact compound identification. Quantitative data was desired from these analyses but problems in both analyses prevented this. The samples analyzed by these techniques were the scrubber water discharge extract (direct inlet probe) and the SASS train organic module extract (GC-MS). Both analyses were performed on the original extract before LC fractionation.

The scrubber water discharge sample was analyzed by EPA at the IERL-RTP laboratory using a capillary inlet "pseudo probe" which should model the direct injection probe mass spectrographic analysis up to mass 350. The results of this analysis are given in Table 85. Although the results are not as definitive as one would like, they are in substantial agreement with the Level 1 LRMS analysis. Carcinogenic compounds were identified at masses 234 (benz(a)anthracene), 252 (benzo(a)pyrene), and 302 (dibenzo(ai + ah)pyrene, the latter two in signficant concentration.

TABLE 85. DIP-MS ANALYSIS OF FURNACE C-2 SCRUBBER WATER

Elution Time, Min.	Molecular Weight Parent Ion	Compound(s) Identified	Relative Intensity	Composition
4.4	202	Pyrene and/or Fluoranthene and a Mixture of Several Possible Anthracene Compounds, such as Dehydro-trans,dimethylethano-	64.5	$C_{16}H_{10}$
	234	Anthracene, benz(a)	5.0	$C_{18}H_{12}$
	228	Anthracene, etc; also possible presence of triphenylene	5.0 5.0	$C_{18}H_{12}$ $C_{18}H_{12}$
6.4	202	Fluoranthene and/or Pyrene 259	100	$C_{16}H_{10}$
	259	Dinitrodiphenylamine (Possible)	1.0	$C_{12}H_9O_4N_3$
10.8	252	Benzo(a)pyrene and/or Perylene and or 10, 11 Benzfluoranthene	100	$C_{20}H_{12}$
11.8	252	Perylene, 10, 11-benzfluoranthene	100	$C_{20}H_{12}$
	282	Possibly 11-Phenyl-9, 10 Ethano-9, 10 - Dihydroanthracene	7.9	$C_{22}H_{18}$
17.4	276	C_{19} or $_{20}$ Ring Compound likely: Benzo(ghi)perylene	100	$C_{22}H_{12}$
20.7	302?	$C_{15/16}$ Benzopyran, Possibly with a Naphthalene Group	100	?

(Continued)

TABLE 85. (Cont'd)

Elution Time, Min.	Molecular Weight Parent Ion	Compound(s) Identified	Relative Intensity	Composition
21.0	302	As Above	100	
23.3	304	Diphenylacenaphthalene	14.2	$C_{24}H_{16}$
24.1	316	C_{23}-Methyl-Phenol(?)	13.4	$C_{23}H?O?$
28.8	300	CHO Compound, C_{20-26}	100	?
	* 302	Dibenzo(ai + ah)pyrene		
	* 300	Coronene		

*Possible assignments based on parent plus p-2 intensity.

The scrubber water discharge sample extract was also analyzed by the Department of Energy's Pittsburgh Energy Technology Center. The results, obtained by high resolution mass spectrographic analysis, are given in Table 86. All of the 16 masses representing the 30 compounds included in the mass spectral screening program for the EPA Level 1 Assessment Plan were detected. The percent relative intensity given is semiquantitative at best and is, therefore, not used in calculating POM generation rates. The significant aspect of this data is that it provides corroborating evidence that mix-sealed furnaces (at least this particular one) generate a variety of compounds of environmental concern and that these materials are captured to some unknown extent by the pollution control equipment.

The SASS train organic module extract sample was analyzed by Stewart Laboratories, Inc. The sample was analyzed on a Finnigan model 4023 GC/MS system using a Finnigan 9610 GC, Wang CO Nova Computer (DCC-116) and Incos data system with 32 K memory and 16-bit word central processing unit.

Two types of GC columns were used: a 1 percent Dexsil 300 on 100/200 mesh supelcoport 1.83 m (6 feet) x 2 mm (0.079 inch) ID glass which was temperature programmed--initial temperature 150°C, held 2 minutes; programmed at 4°C/min to 300°C; and a 1.5 percent SP-301 (liquid crystal) on 100/200 mesh supelcoport 1.83 m (6 feet) x 2 mm (0.079 inch) ID glass which was temperature programmed --initial temperature 260°C, held 2 minutes; programmed to 290°C at 4°C/minute.

Although the results, presented in Tables 87 and 88, provide excellent identification of the compounds present, quantitation was not possible because of a problem with the sample (The dilution response was not linear and seemed to indicate the presence of very fine suspended solids in the original sample.) Therefore, a comparison of relative response factors is the only indication of relative concentrations available. This measure appears under the columns headed RIC.

Positive compound identifications are based on a matching of gas chromatographic retention times with those of known standards as well as matching of mass spectra with known standards and a computerized library search of the 26,500 entry NIH/EPA mass spectra library. Tentative identifications are based on computer matching of mass spectra with the NIH/EPA reference library.

TABLE 86. HIGH RESOLUTION MASS SPECTROGRAPHIC ANALYSIS OF FURNACE C-2 SCRUBBER DISCHARGE WATER EXTRACT

Mass				Formula			
Calculated	Measured	ΔMMU*	Percent Relative Intensity	C	H	N	Possible Compounds
166.0783	166.0759	2	7.8	13	10		Fluorene
178.0783	178.0780	0	43.9	14	10		Anthracene Phenanthrene
179.0735	179.0804	7	1.2**	13	9	1	Acridine
202.0783	202.0775	1	100.0	16	10		Pyrene Fluoranthene
216.0939	216.0910	3	10.9	17	12		Benzo(a)fluorene Benzo(b)fluorene
228.0939	228.0928	1	25.7	18	12		Chrysene Triphenylene Benzo(a)anthracene Benzo(c)phenanthrene
252.0939	252.0931	1	51.5	20	12		Benzo(b)fluoranthene Benzo(j)fluoranthene Benzo(k)fluoranthene Benzo(a)pyrene Benzo(e)pyrene Perylene
254.1095	254.0944	15	4.7	20	14		Cholanthrene [Benz(j)aceanthrylene]
256.1252	256.1076	18	1.5	20	16		7,12-Dimethylbenz(a)anthracene
267.1048	267.1049	5	1.5	20	13	1	Dibenzo(c,g)carbazole

*Difference between measured and calculated mass in millimass units.

**Corrected for C_{13} contribution.

TABLE 86. (Continued)

Mass		ΔMMU*	Percent Relative Intensity	Formula			Possible Compounds
Calculated	Measured			C	H	N	
268.1252	268.0978	27	2.3	21	16		3-Methylcholanthrene
276.0939	276.0936	0	14.9	22	12		Benzo(ghi)perylene
278.1095	278.1082	1	3.8	22	14		Dibenz(a,b)anthracene
279.1090	279.1048	4	0.2**	21	13	1	Dibenz(a,j)acridine Dibenz(a,b)acridine
300.0939	300.0932	1	0.9	24	12		Coronene
302.1095	302.1067	3	1.1	24	14		Dibenzo(a,b)pyrene Dibenzo(a,i)pyrene Dibenzo(b,def)chrysene

*Difference between measured and calculated mass in millimass units.

**Corrected for C_{13} contribution.

TABLE 87. RESULTS FROM 1 % DEXSIL 300 COLUMN, SAMPLE C2-X

Compound	Scan No.	Ret. Time	Base m/e	Best Computer Match				RIC
				Name	Purity	Fit	Refit	
Fluorene*	45	1:30	166	Fluorene	903	974	913	686080
Unidentified	75	2:30	166					176384
Unidentified	170	5:40	184					132863
Phenanthrene	200	6:40	178	Phenanthrene	929	989	935	334336
Anthracene	200	6:40	178	Anthracene	890	993	890	
9-methylphenanthrene*	284	9:28	192	9-methyl phenanthrene	774	814	931	13743
Cyclopenta(def)phenanthrene*	293	9:44	190	Cyclopenta(def)-phenanthrene	829	908	847	99199
Fluoranthene	409	13:38	202	Fluoranthene	961	987	968	251648
Unidentified PAH	422	14:04	202					52287
Pyrene	444	14:48	202	Pyrene	959	988	965	261119
Benzo(a)fluorene*	516	17:12	216	Benzo(a)fluorene	797	823	864	5000
Methyl Pyrene* and/or Benzo(b)fluorene*	547	18:14	216					1212
Unidentified PAH	617	20:34	234					2975
Unidentified PAH	630	21:00	226					16016
Benzo(ghi)fluoranthene*	663	22:06	226	Benzo(ghi)fluoranthene	828	909	835	81152
Diisooctyl Phthalate	686	22:52	149		784	859	828	34687

*Indicates a compound tentatively identified by matching spectra with NIH/EPA mass spectra reference library.

(Continued)

TABLE 87. (Cont'd)

Compound	Scan No.	Ret. Time	Base m/e	Best Computer Match				RIC
				Name	Purity	Fit	Refit	
Unidentified	772	25:44	152	Acenaphtylene	872			22272
Benzo(j)fluoranthene* and/or benz(e)acephenanthrylene*	851	28:22	252		912 909	961 960	939 } 939	32032
Unidentified PAH	868	28:56	252	Benzo(k)fluoranthene	842			1480
Benzo(a)pyrene } Benzo(e)pyrene	895	29:50	252					22400
Perylene	913	30:26	252	Perylene	854	857	985	4004
Indeno(1,2,3-cd)pyrene	1064	35:28	276		905	926	958	9951
Benzo(ghi)perylene	1097	36:34	276		894	943	941	29599
Anthanthrene*	1113	37:06	276					7560
Coronene	1292	43:04	300		769	826	867	9423

*Indicates a compound tentatively identified by matching spectra with NIH/EPA mass spectra reference library.

TABLE 88. RESULTS FROM 1.5 % SP301 LIQUID CRYSTAL COLUMN, SAMPLE C2-X

Compound	Scan No.	Base m/e	Best Computer Match				RIC
			Name	Purity	Fit	Refit	
Unidentified PAH	28	226					69888
Benzo(ghi)fluoranthene*	40	226	Benzo(ghi)fluoranthene	953	977	969	149504
Benz(a)anthracene	44	228					69632
Chrysene	57	228					53248
Unidentified	92	240					4480
Benzo(j)fluoranthene* and/or benz(e)acephenanthrylene*	121	252	Benzo(j)fluoranthene Benz(e)acephenanthrylene	940 930	990 985	946 942 }	33280
Benzo(e)pyrene	134	252					5256
Benzo(k)fluoranthene	141	252	Supelco literature reference match				3656
Perylene	168	252					4208
Benzo(a)pyrene	217	252					10864

*Indicates a compound tentatively identified by matching spectra with NIH/EPA mass spectra reference library.

Listed in Table 89 are the 13 positively identified and 10 tentatively identified polynuclear aromatic hydrocarbon in the furnace C-2 SASS organic module catch.

Also included in this table is the normalized relative concentration in the sample, the estimated maximum concentration in the cleaned gas (after scrubbing but before flaring) of the primary control system of furnace C-2, and the DMEG[42] values for the compounds.

The normalized relative concentrations and estimated concentration in the cleaned gas were calculated as follows. The first assumption made is that since the same sample was analyzed on both columns the RIC value obtained for identical compounds should be the same in both cases. Since this is not the case (possibly due to sample size variation, response of the instrument or or other factors), the RICs in Table 88 were multiplied by the ratio of RICs for the sum of benzo(a)- and berzo(e)pyrene obtained in the two analyses (22,400 ÷ (5,256 + 10,864) = 1.39). The next step was to sum all the RICs given in Table 87 and the modified RICs from Table 88 for compounds not given in Table 87. The individual compound RICs were then divided by the RIC sum to obtain the normalized relative sample concentration (this only sums to 83 percent in Table 89 because the unidentified PAHs are not included). These relative sample concentrations were then multiplied by the estimated concentration of aromatic hydrocarbons (268.73 mg/m^3) given in Table 83.

In this calculation, the RICs were adjusted based on the benzo(a)- and benzo(e)pyrene figures. If other compounds found in both Tables 87 and 88 were used to make this modification, a slight difference in the final result would be obtained. It must also be understood that this method of estimating the concentration of PAHs in the cleaned scrubber gas is not considered to be very accurate and should be considered only as giving the order of magnitude of the different compounds in the unflared gas.

The positive identification includes four known carcinogens, benzo(a)-anthracene, chrysene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene. Benz(a)-anthracene may exceed the DMEG limit by a factor of over 200. Benzo(a)pyrene may exceed the DMEG value by a factor of 10^5. The tentative identifications include one known carcinogen (benzo(j)fluoranthene) which may slightly exceed the DMEG value.

TABLE 89. ESTIMATED CONCENTRATIONS OF IDENTIFIED PAHs

Compound	Mass	Carcinogen Rating[a]	Normalized Relative Sample Concentration	Estimated Concentrations in Unflared Gas	
				mg/Nm^3	DMEG[42] Air Health Limit, mg/Nm^3
Phenanthrene	178	-	6.8	18.3	1.6
Anthracene	178	-	6.8	18.3	56
Fluoranthene	202	-	10.2	27.4	90
Pyrene	202	-	10.6	28.5	230
Benz(a)anthracene	228	+	3.9	10.5	0.045
Chrysene	228	±	3.0	8.1	2.2
Benzo(e)pyrene	252	-	0.30	0.81	3.0
Benzo(k)fluoranthene	252	-	0.06	0.16	1.6
Perylene	252	-	0.16	0.43	-
Benzo(a)pyrene	252	+++	0.61	1.64	2×10^{-5}
Indeno(1,2,3-cd)pyrene	276	+	0.41	1.10	1.6
Benzo(ghi)perylene	276	-	1.20	3.2	-
Coronene	300	-	0.38	1.0	-
Fluorene*	166	-	27.9	75.0	-
9-Methylphenanthrene*	192	-	0.56	1.5	-

[a] ± weakly carcinogenic, + carcinogenic, ++ and +++ strongly carcinogenic, - not carcinogenic.

* Tentative identification.

(Continued)

TABLE 89. (Cont'd)

Compound	Mass	Carcinogen Rating[a]	Normalized Relative Sample Concentration	Estimated Concentrations in Unflared Gas	
				mg/Nm^3	DMEG Air Health Limit, mg/Nm^3
Cyclopenta(def) phenanthrene*	190	-	4.0	10.7	-
Benzo(a)fluorene*	216	-	0.20	0.54	-
Methyl Pyrene*	216	-	0.025	0.07	-
Benzo(b)fluorene*	216	-	0.025	0.07	-
Benzo(ghi)fluoranthene*	226	-	3.3	8.9	-
Benzo(j)fluoranthene*	252	++	1.3	3.5	6.5
Benzo(e)acephenanthrylene*	252	?	1.3	3.5	-
Anthanthrene*	276	-	0.31	0.83	-

[a] ± Weakly carcinogenic, + carcinogenic, ++ and +++ strongly carcinogenic, - not carcinogenic.

*Tentative identification.

12.3.8 Plant C Final Wastewater Discharge

All process wastewater flows to a common sump where lime and chlorine are added. The water then flows to pond No. 5 (which is full of solids) and then through a series of ponds where solids settle out and additional lime and chlorine are added. The ponds are allowed to fill up and new ones built as needed. The treated process discharge then flows into a small pond where it joins other plant wastewaters (sanitary and furnace cooling). Two samples were taken: a grab sample of the pond No. 5 outlet, which is essentially the combined partially treated total process discharge (since no settling occurs in pond No. 5); and a grab sample of the treated process discharge just before it enters the final pond and before mixing with other wastewaters. Total flow at both locations was estimated to be 5.68 m^3/min (1500 gpm). Both samples were filtered for suspended solids determination, the solids and liquid phases separately extracted, TCO and GRAV run on each extract, the extracts for each sample combined and concentrated and subjected to TCO, GRAV, LC, TCO, GRAV, and IR. LRMS analysis was done on LC fractions 2 and 3 of each sample. Summarized in Table 90 are the overall results for solids and organics, and summarized in Tables 91 and 92 are the level 1 organic analyses. The LC, IR, and LRMS data are in the appendices.

TABLE 90. PLANT C EFFLUENTS

Untreated Plant Wastewater

Sample Point - Pond 5 outlet (some chlorine added, essentially no solids removal).

Estimated Flow Rate: 5.68 m^3/min (1500 gpm)

Component	Weight Collected, mg	Concentration mg/L	kg per day
Suspended Solids	4,256	1100	9000
Organics	313.8	81.0	660

Treated Plant Wastewater

Sample Point - At entrance to final equilization pond (after chlorination and solids removal).

Table 90 (Continued)

Component	Weight Collected, mg	Concentration mg/L	kg per Day
Suspended Solids	66.0	17.8	145
Organics	19.5	8.0	65

For the pond No. 5 outlet water, about 99 percent of the organic was found to be associated (adsorbed) with the solids. A variety of compound categories, Table 91, were found in the waste. Aromatic hydrocarbons (including halogenated types) make up the largest categories found (total 34 mg/L). LRMS analysis indicates a substantial concentration of fused aromatics with molecular weights between 223 and 376. Indications of at least 16 different fused aromatics were found. Major intensities were found at masses 252, 266, 276, and 302 which indicates the possible presence of substantial concentrations of the carcinogens benzo(a)pyrene, dibenzofluorene, indenopyrene, and dibenzochrysene isomer, respectively. Minor intensities were also found at masses 228 (chrysene), 242 (methyl chrysene), and 292 (methyl dibenzoanthracene), all carcinogens.

For the treated process wastewater, about 25 percent of the organic matter is associated with the solids. Organics in the wastewater were fairly evenly divided (Table 92) over all compound categories. Aromatic hydrocarbons accounted for only about 0.15 mg/L of the total organic. LRMS analysis gave evidence of fused aromatics at masses 228 (chrysene) and 252 (benzo(a)pyrene), both carcinogens.

12.3.9 Plant C Summary

Sampling was conducted at this plant to compare two similar mix-sealed furnaces producing different products. Furnace C-1 was producing 75 percent FeSi and furnace C-2 was producing 50 percent FeSi. The results, Table 93, indicate that the furnaces produce equivalent amounts of particulate matter on a kg/hr or kg/Mw-hr basis and that the scrubbers on furnace C-1 are more efficient. The particulate in the scrubbed gases of both furnaces would exceed NSPS limits of 0.45 kg/ Mw-hr. The amount (per Mw) of organic generated by furnace C-1 is more than double that of furnace C-2. This may be

TABLE 91. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C-P50

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/L	6.45	11.0	37.0	9.7	7.7	14.8	0.85	87.6
TCO, mg/L	1.1	2.9	1.0	0.8	1.5	2.6	0	10.0
GRAV, mg/L	5.35	8.1	36.0	8.9	5.2	12.2	0.85	77.6

Category Assigned Intensity - mg/L

Category	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Aliphatic Hydrocarbons	100/1.6	--	--	--	--	--	--	1.6
Halogenated Aliphatics	100/1.6	100/3.5	--	--	--	--	--	5.1
Aromatic Hydrocarbons	100/1.6**	100/3.5	100/11.9	--	--	--	--	17.0
Halogenated Aromatics	100/1.6**	100/3.5	100/11.9	--	--	--	--	17.0
Silicones	--	10/0.35	10/1.19	10/0.13	--	--	--	1.67
Heterocyclic O Compounds	--	--	100/11.9	100/1.3	--	--	--	13.2
Nitroaromatics	--	--	--	10/0.13	10/0.1	--	--	0.23
Ethers	--	--	--	10/0.13	100/1.0	--	--	1.13
Aldehydes	--	--	--	100/1.3	10/0.1	--	--	1.4
Phosphates	--	--	--	10/0.13	10/0.1	10/0.26	10/0.02	0.51
Nitriles	--	--	--	10/0.13	10/0.1	--	--	0.23
Heterocyclic N Compounds	--	--	--	100/1.3	100/1.0	100/2.6	10/0.02	4.92
Heterocyclic S Compounds	--	--	--	100/1.3	100/1.0	--	--	2.3
Alcohols	--	--	--	100/1.3**	100/1.0	100/2.6	100/0.2	5.1
Phenols	--	--	--	--	10/0.1	10/0.26	10/0.02	0.38
Ketones	--	--	--	100/1.3**	100/1.0	100/2.6	10/0.02	4.92

(Continued)

*Quantity Not Sufficient.

**Possible Contamination.

TABLE 91. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C-P50 (Cont'd)

Category	Assigned Intensity - mg/L							
Amines	--	--	--	100/1.3**	100/1.0	100/2.6	100/0.2	5.1
Alkyl S Compounds	--	--	--	--	10/0.1	10/0.26	10/0.02	0.38
Sulfuric Acids	--	--	--	--	10/0.1	10/0.26	10/0.02	0.38
Sulfoxides	--	--	--	--	10/0.1	10/0.26	10/0.02	0.38
Amides	--	--	--	--	10/0.1	10/0.26	10/0.02	0.38
Carboxylic Acids	--	--	--	--	10/0.1	100/2.6	100/0.2	2.9
Esters	--	--	--	--	100/1.0	10/0.26	10/0.02	1.28

*Quantity Not Sufficient. **Possible Contamination

TABLE 92. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C-TPD

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/L	0.2	0.25	1.6	1.05	0.7	4.3	0.45	8.55
TCO, mg/L	0.2	0	0.8	0	0.35	0.3	0	1.65
GRAV, mg/L	0	0.25	0.8	1.05	0.35	4.0	0.45	6.9

Category Assigned Intensity - mg/L

Aliphatic Hydrocarbons	100/0.1	--	--	--	--	--	--	0.1
Halogenated Aliphatics	100/0.1	100/0.08	--	--	--	--	--	0.18
Aromatic Hydrocarbons	--	10/0.008	10/0.067	--	--	--	--	0.075
Halogenated Aromatics	--	10/0.008	10/0.067	--	--	--	--	0.075
Silicones	--	10/0.008	10/0.067	10/0.12	--	--	--	0.195
Heterocyclic O Compounds	--	--	10/0.067	10/0.12	--	--	--	0.187
Nitroaromatics	--	--	--	10/0.12	10/0.04	--	--	0.16
Ethers	--	--	--	10/0.12	10/0.04	--	--	0.16
Aldehydes	--	--	--	10/0.12	10/0.04	--	--	0.16
Phosphates	--	--	--	10/0.12	10/0.04	10/0.2	10/0.015	0.375
Nitriles	--	--	--	10/0.12	10/0.04	--	--	0.16
Heterocyclic N Compounds	--	--	--	10/0.12	10/0.04	10/0.2	10/0.015	0.375
Heterocyclic S Compounds	--	--	--	10/0.12	10/0.04	--	--	0.16
Alcohols	--	--	--	--	10/0.04	10/0.2	10/0.015	0.255
Phenols	--	--	--	--	10/0.04	10/0.2	10/0.015	0.255
Ketones	--	100/0.08**	100/0.67**	--	10/0.04	10/0.2	100/0.15	1.14

(Continued)

*Quantity Not Sufficient. **Possible Contamination.

TABLE 92. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C-TPD (Cont'd)

Category	Assigned Intensity - mg/L							
Amines	--	--	--	--	10/0.04	10/0.2	10/0.015	0.255
Alkyl S Compounds	--	--	--	--	10/0.04	10/0.2	10/0.015	0.255
Sulfuric Acids	--	--	--	--	10/0.04	10/0.2	10/0.015	0.255
Sulfoxides	--	--	--	--	10/0.04	100/2.0	10/0.015	2.055
Amides	--	--	--	--	10/0.04	10/0.2	10/0.015	0.255
Carboxylic Acids	--	--	--	--	10/0.04	10/0.2	10/0.015	0.255
Esters	--	100/0.08**	100/0.67**	--	10/0.04	10/0.2	100/0.15	1.14

*Quantity Not Sufficient. **Possible Contamination.

TABLE 93. DATA COMPARISON, FURNACES C-1 AND C-2

Furnace No.	Component	Remaining in Cleaned Gas[a] kg/hr	kg/Mw-hr	kg/Mg Alloy	Total Generated[b] kg/hr	kg/Mw-hr	kg/Mg Alloy
C-1	Particulate	7.75	0.50	4.1	196.7	12.7	103.0
C-2	Particulate	12.96	0.77	4.75	187.9	11.2	68.9
C-1	Organic	4.58	0.30	2.4	19.6	1.27	10.3
C-2	Organic	2.04	0.12	0.75	9.9	0.59	3.6

[a] After scrubber but before flare.

[b] Sum of component in scrubber discharge gas and scrubber water. The data do not include secondary fumes from furnace covers, etc.

related to the higher proportion of coal or wood chips used in furnace C-1. The scrubbers on neither furnace provide good control of particulate or organic matter. The particulate matter going to the flares of furnace C-1 is between 2.8 and 8.0 percent organic matter while the organic content of furnace C-2 unflared particulates is between 2 and 4.5 percent.

Detailed analysis indicates that very high levels of carcinogens, including benzo(a)pyrene may be emitted to the atmosphere from both furnaces. GC-MS analysis of the scrubbed but unflared gas from furnace C-2 gave positive identification of 13 polynuclear aromatic hydrocarbons (PAHs) and tentative identification for 10 additional PAH. These include five known carcinogens including benz(a)anthracene and benzo(a)pyrene. Estimated concentrations of these two carcinogens are greater than DMEG levels by factors of 233 and 8×10^4, respectively. The analyses also indicates that carcinogens are contained in the scrubber discharge water and are probably adsorbed on the particulate matter. There is a high probability, therefore, that the sludge ponds at the plant site (unlined) also contain substantial amounts of fused aromatics and carcinogens. There is some evidence that the plant final wastewater discharge may also contain low concentrations of one or more carcinogens.

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APPENDIX A

INFRARED ANALYSIS REPORTS

TABLE A-1. IR REPORT--SAMPLE NO. A1X, CUT LC-1

- Quantity Not Sufficient -

TABLE A-2. IR REPORT--SAMPLE NO. A1X, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2920	S	Sat'd C-H	
2850	M	Sat'd C-H	

TABLE A-3. IR REPORT--SAMPLE NO. A1X, CUT LC-3, 4 & 5

- Quantity Not Sufficient -

TABLE A-4. IR REPORT--SAMPLE NO. A1X, CUT LC-6

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2936	S	Sat'd C-H	
2866	M	Sat'd C-H	
1731	S	Ketone, Ester	
1457	M	Sat'd C-H	
1379	M	Sat'd C-H	
1277	S	Ketone, Phosphate	
1175	W	Ester	
1112	M	Phosphate	
714	W	Alkyl	

TABLE A-5. IR REPORT--SAMPLE NO. A1X, CUT LC-7

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2936	S	Sat'd C-H	
2866	M	Sat'd C-H	
1739	S	Ketone, Ester	
1457	M	Sat'd C-H	
1379	M	Sat'd C-H	
1254	M	Ketone	
1175	M	Ester	

TABLE A-6. IR REPORT--SAMPLE NO. A1SWD, CUT LC-1, 2, 3, & 4

- Quantity Not Sufficient -

TABLE A-7. IR REPORT--SAMPLE NO. A1SWD, CUT LC-5

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2934, 2967	S	Sat'd C-H	
2857	M	Sat'd C-H	
1729	M	Ketone	
1450	W	Sat'd C-H	
1264	S	Ketone, Phosphate	
1018-1100	S	Phosphate, Ether	Broad
804	S	Phosphate	
749	W	Alkyl, Phosphate	

TABLE A-8. IR REPORT--SAMPLE NO. A1SWD, CUT LC-6

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2868, 2967	M	Sat'd C-H	
2934	S	Sat'd C-H	
1740	S	Ketone, Ester	
1456	W	Sat'd C-H	
1379	W	Sat'd C-H	
1140-1240	M	Ester, Silicone Ketone	Broad
1083	W	Silicone	
749	W	Alkyl	

TABLE A-9. IR REPORT--SAMPLE NO. A1SWD, CUT LC-7

- Quantity Not Sufficient -

TABLE A-10. IR REPORT--SAMPLE NO. A-FE, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2933, 2972	S	Sat'd C-H	
2862	M	Sat'd C-H	
1733	S	Ketone	Poss. Contamination
1465	M	Sat'd C-H	
1279	S	Ketone, C-F	
1120	M	C-F, Sat'd C-H	

TABLE A-11. IR REPORT--SAMPLE NO. A-FE, CUT LC-2

- Quantity Not Sufficient -

TABLE A-12. IR REPORT--SAMPLE NO. A-FE, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2928, 2966	S	Sat'd C-H	
2857	W	Sat'd C-H	
1739	S	Ketone	Poss. Contamination
1460	W	Sat'd C-H	
1262	S	Ketone, Silicone	
1087	S	Silicone, C-F	
1021	S	Silicone, C-F	
797	S	Alkyl, Silicone	
687	W	Alkyl, C-Cl	

TABLE A-13. IR REPORT--SAMPLE NO. A-FE, CUT LC-4 & 5

- Quantity Not Sufficient -

TABLE A-14. IR REPORT--SAMPLE NO. A-FE, CUT LC-6

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2828	S	Sat'd C-H	
2857	M	Sat'd C-H	

TABLE A-15. IR REPORT--SAMPLE NO. A-FE, CUT LC-7

- Quantity Not Sufficient -

TABLE A-16. IR REPORT--SAMPLE NO. A2X, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3201	M	O-H	Poss. Contamination Broad
3068	W	Unsat'd C-H	
2928	S	Sat'd C-H	
2858, 2959	M	Sat'd C-H	
1457	M	Sat'd C-H, Alcohol	
1379	W	Sat'd C-H	
1199	M	Aromatic C-H, Alcohol, Phenol	
815	M	Subst. Aromatic	
737	M	Alkyl, C-Cl, Alcohol	

TABLE A-17. IR REPORT--SAMPLE NO. A2X, CUT LC-2, 3, & 4

- Quantity Not Sufficient -

TABLE A-18. IR REPORT--SAMPLE NO. A2X, CUT LC-5

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2928, 2959	S	Sat'd C-H	
2873	M	Sat'd C-H	
1738	S	Ketone, Ester	
1252	M	Ketone, Ester Silicone	
1175	W	Sat'd C-H, Ester	
1020	M	Silicone	
800	M	Alkyl, Silicone	

TABLE A-19. IR REPORT--SAMPLE NO. A2X, CUT LC-6

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3374	S	O-H	Broad
2944	S	Sat'd C-H	
2865	M	Sat'd C-H	
1730	S	Ester, Ketone	
1370, 1456	M	Sat'd C-H, Alcohol	
1260	S	Alcohol	
1174	S	Ester	Doublet
1072	M	Alcohol	Doublet
838	W	Alkyl	
720	W	Alkyl, Alcohol	

TABLE A-20. IR REPORT--SAMPLE NO. A2X, CUT LC-7

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3500	W	O-H	Broad
2936	M	Sat'd C-H	
2865	M	Sat'd C-H	
1738	S	Ester, Ketone	
1464, 1378	W	Sat'd C-H	
1245	M	Ester, Ketone Alcohol	
1182	M	Ester, Alcohol	Broad

TABLE A-21. IR REPORT--SAMPLE NO. A2SWD, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2934	S	Sat'd C-H	
2868	M	Sat'd C-H	
842	W	Alkyl	
749	S	Alkyl, C-Cl	
711	W	C-Cl	

TABLE A-22. IR REPORT--SAMPLE NO. A2SWD, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3060	M	Unsat'd C-H	
2972	W	Sat'd C-H	
2868	W	Sat'd C-H	
1439	M	Sat'd C-H	
1264	W	Sat'd C-H	
1182	W	Sat'd C-H/ Aromatic C-H	
842	M	Subst. Olefin/ Aromatic	
815	M	Subst. Olefin/ Aromatic	
749	S	Subst. Aromatic, C-Cl	

TABLE A-23. IR REPORT--SAMPLE NO. A2SWD, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3060	W	Unsat'd C-H	
2934, 2967	M	Sat'd C-H	
2868	W	Sat'd C-H	
1740	S	Ester, Ketone	Poss. Contamination
1461, 1379	W	Sat'd C-H	
1138-1275	M	Ester, Ketone	Broad
1138	W	Aromatic C-H	
815, 946	W	Subst. Olefin/ Aromatic	
749	M	Subst. Aromatic, C-Cl	

TABLE A-24. IR REPORT--SAMPLE NO. A2SWD, CUT LC-4

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2939	M	Sat'd C-H	Broad
1187	M	Sat'd C-H, Ether	Broad
974	M	Alkyl	Broad
749	S	Alkyl, C-CL	

TABLE A-25. IR REPORT--SAMPLE NO. A2SWD, CUT LC-5

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2934	S	Sat'd C-H	
2868, 2967	M	Sat'd C-H	
1275	W	Sat'd C-H	
749	S	Alkyl, C-Cl	

TABLE A-26. IR REPORT--SAMPLE NO. A2SWD, CUT LC-6 & 7

- Quantity Not Sufficient -

TABLE A-27. IR REPORT--SAMPLE NO. B1PW, CUT LC-1

- Quantity Not Sufficient -

TABLE A-28. IR REPORT--SAMPLE NO. B1PW, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2967	W	Sat'd C-H	
1254	W	Sat'd C-H	
1081	S	Ether	Poss. Contamination
847	M	Alkyl	
698, 752	W	Alkyl, C-Cl	

TABLE A-29. IR REPORT--SAMPLE NO. B1PW, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3460	W	N-H, O-H	Poss. Contamination Broad
2732, 2866, 2959	S	Sat'd C-H	
1739	S	Ester	Poss. Contamination
1606	W	Amine	Doublet
1379, 1465	M	Sat'd C-H	
1081-1183	S	Ester, Amine, Alcohol	Broad
964	W	Alkyl	
847	M	Amine	
752	M	Alkyl, C-Cl, Amine	

TABLE A-30. IR REPORT--SAMPLE NO. B1PW, CUT LC-4

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3450	W	N-H, O-H	Broad Poss. Contamination
2936, 2967	S	Sat'd C-H	
2873	M	Sat'd C-H	
1739	S	Ketone	
1582	W	Amine	Doublet
1379, 1465	M	Sat'd C-H	
1277	S	Ketone, Alcohol	
1128	M	Amine, Alcohol	
1074	M	Amine, Alcohol, Ether	
964	W	Alkyl	
846	W	Amine	
745	W	Alkyl, Amine, Alcohol	

TABLE A-31. IR REPORT--SAMPLE NO. B1PW, CUT LC-5

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2928, 2967	S	Sat'd C-H	
2865	M	Sat'd C-H	
1730	S	Ester, Ketone	
1375, 1455	W	Sat'd C-H	
1268	S	Ketone	
1213	M	Ester	
1127	M	Ether	
1080	M	Ether	

TABLE A-32. IR REPORT--SAMPLE NO. B1PW, CUT LC-6

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3460	M	N-H, O-H	Broad
3295	W	N-H, O-H	Shoulder
2857, 2936	S	Sat'd C-H	
1738	S	Ester, Ketone	
1605	W	Amine	
1378, 1464	M	Sat'd C-H, Alcohol	
1080-1252	S	Alcohol, Sulfonic Acid, Amine, Ester, Ketone	
845	W	Amine	
751	W	Alkyl, Amine, Alcohol	
712	W	Alkyl, Amine, Alcohol	

TABLE A-35. IR REPORT--SAMPLE NO. B1X, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3067	W	Unsat'd C-H	Multiplet
2975	M	Sat'd C-H	
2912	W	Sat'd C-H	
1260	S	Silicone, C-F	
1072	S	C-F, Silicone	Broad
845	M	Subst. Aromatic, Olefinic C-H	
806	S	Subst. Aromatic, Olefinic C-H	

TABLE A-36. IR REPORT--SAMPLE NO. B1X, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3077	W	Unsat'd C-H	Multiplet
2967	M	Sat'd C-H	
2912	W	Sat'd C-H	
1260	S	Silicone, C-F,	
1080	S	Silicone, C-F	Broad
842	M	Subst. Aromatic, Olefinic C-H	
806	S	Subst. Aromatic, Olefinic C-H	

TABLE A-37. IR REPORT--SAMPLE NO. B1X, CUT LC-4

- Quantity Not Sufficient -

TABLE A-38. IR REPORT--SAMPLE NO. B1X, CUT LC-5

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2967	M	Sat'd C-H	
2873	W	Sat'd C-H	
1722 (1600-1722)	M	Ketone, Amide	Broad
1260	S	Phosphate, Ketone	
1088, 1033	S	Phosphate, Sulfoxide	Broad Doublet
806	S	Phosphate	

TABLE A-39. IR REPORT--SAMPLE NO. B1X, CUT LC-6

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3398	S	O-H, N-H	Very Broad
2936, 2967	W	Sat'd C-H	
1652 (1620-1720)	S	Amide, Amine	Broad
1550	W	Amine	
1456	W	Sat'd C-H	
1393	M	Alcohol	
1260	M	Amide, Alcohol	
1088	M	Alcohol, Amine	Broad
806	M	Sat'd C-H	
712	W	Alcohol, Amine	

TABLE A-40. IR REPORT--SAMPLE NO. B1X, CUT LC-7

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2865, 2928	M	Sat'd C-H	
1739	S	Ester, Ketone	
1457, 1371	W	Sat'd C-H	
1136	M	Ester, Alkyl	Broad

TABLE A-41. IR REPORT--SAMPLE NO. B2PW, F, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2928	S	Sat'd C-H	
2857	M	Sat'd C-H	
1456	W	Sat'd C-H	
1378	W	Sat'd C-H, C-F	

TABLE A-42. IR REPORT--SAMPLE NO. B2PW, F, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2928	S	Sat'd C-H	
2857	M	Sat'd C-H	
1456	W	Sat'd C-H	
1378	W	Sat'd C-H, C-F	

TABLE A-43. IR REPORT--SAMPLE NO. B2PW, F, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3053	M	Unsat'd C-H	
2928	S	Sat'd C-H	
2865	M	Sat'd C-H	
1604	M	Aromatic C=C	
1456	M	Sat'd C-H	
1378	W	Sat'd C-H, C-F	
814, 884	M	Subst. Aromatic, Olefin	
751	S	Alkyl, Subst. Aromatic, C-Cl	

TABLE A-44. IR REPORT--SAMPLE NO. B2PW, F, CUT LC-4

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2936, 2959	S	Sat'd C-H	
2865	M	Sat'd C-H	
1730	S	Ketone	Poss. Contamination
1464	M	Sat'd C-H	
1378	W	Sat'd C-H, C-F	
1276	S	Silicone, Ketone	
1127	M	Ether	
1072	M	Ether, Silicone,	
743	W	Alkyl	

TABLE A-45. IR REPORT--SAMPLE NO. B2PW, F, CUT LC-5 & 6

- Quantity Not Sufficient -

TABLE A-46. IR REPORT--SAMPLE NO. B2PW, F, CUT LC-7

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2928, 2967	M	Sat'd C-H	
2857	W	Sat'd C-H	
1730	S	Ketone	
1456	W	Sat'd C-H	
1284	M	Ketone	
1127	W	Sat'd C-H	
1072	W	Sulfoxide	

TABLE A-47. IR REPORT--SAMPLE NO. B2X, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3053	W	Unsat'd C-H	
2857, 2928, 2959	S	Sat'd C-H	
1511, 1597	W	Aromatic C=C	
1378, 1464	M	Sat'd C-H	
1268	W	Alkyl, C-F	
955, 1010	W	Aromatic C-H	
818	W	Olefin, Subst. Aromatic	
783	M	Subst. Aromatic, Alkyl, C-Cl	

TABLE A-48. IR REPORT--SAMPLE NO. B2X, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3053	M	Unsat'd C-H	
2857, 2928, 2959	S	Sat'd C-H	
1604	W	Aromatic C=C	
1456	M	Sat'd C-H	
1370	W	Sat'd C-H	
1260	W	Alkyl, C-F, Silicone	
1190	W	Aromatic C-H, Alkyl, C-F	
1080	W	Aromatic C-H, C-F, Silicone	
829	M	Subst. Aromatic, Olefin	
775	M	Subst. Aromatic, Alkyl, C-Cl	
751	M	Subst. Aromatic, Alkyl, C-Cl	

TABLE A-49. IR REPORT--SAMPLE NO. B2X, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3053	M	Unsat'd C-H	
2959	W	Sat'd C-H	
2858, 2928	S	Sat'd C-H	
1457	M	Sat'd C-H	
1375	W	Sat'd C-H, C-F	
1277	W	Sat'd C-H, C-F	
1191	W	Sat'd C-H, Aromatic C-H, C-F	
831	W	Subst. Aromatic, Olefin	
753, 784	S	Subst. Aromatic, Alkyl, C-Cl	

TABLE A-50. IR REPORT--SAMPLE NO. B2X, CUT LC-4

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2928	S	Sat'd C-H	
2866, 2959	M	Sat'd C-H	Poss. Contamination
1723	S	Ketone	
1465	M	Sat'd C-H	
1285	M	Sat'd C-H, Ketone	
1128	M	Sat'd C-H, Ether	

TABLE A-51. IR REPORT--SAMPLE NO. B2X, CUT LC-5-7

- Quantity Not Sufficient -

TABLE A-52. IR REPORT--SAMPLE NO. B2SWD, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2868, 2934	S	Sat'd C-H	
749	M	Alkyl, C-Cl	

TABLE A-53. IR REPORT--SAMPLE NO. B2SWD, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3060	S	Unsat'd C-H	
2972	M	Sat'd C-H	
2923	S	Sat'd C-H	
1910	W	Aromatic Overtone	
1603	M	Aromatic C=C	
1456	M	Sat'd C-H	
1258	W	Sat'd C-H	
1187	W	Sat'd C-H, Aromatic C-H	
946, 1034	W	Aromatic C-H	
815, 881	M	Subst. Aromatic	
749	S	Subst. Aromatic, C-Cl	

TABLE A-54. IR REPORT--SAMPLE NO. B2SWD, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3060	M	Unsat'd C-H	
2967	M	Sat'd C-H	
1724	M	Ketone	Poss. Contamination
1450	M	Sat'd C-H	
1275	W	Ketone	
810, 881	W	Subst. Olefin/ Aromatic	
749	S	Subst. Aromatic, C-Cl	

TABLE A-55. IR REPORT--SAMPLE NO. B2SWD, CUT LC-4

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3060	W	Unsat'd C-H	
2934, 2967	S	Sat'd C-H	
2873	W	Sat'd C-H	
1740	S	Ketone, Ester	
1461	M	Sat'd C-H	
1384	W	Sat'd C-H	
1181-1269	M	Ester, Ether, Ketone	Broad
1138	W	Aromatic C-H, Sat'd C-H	
749	S	Subst. Aromatic, Alkyl	

TABLE A-56. IR REPORT--SAMPLE NO. B2SWD, CUT LC-5

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3043	W	Unsat'd C-H	
2934	S	Sat'd C-H	
2868	M	Sat'd C-H	
1707	M	Ketone	
1598	S	Aromatic C=C	
1461	M	Sat'd C-H	
1357	M	Sat'd C-H	
1149-1264	M	Ketone, Ether	Broad
1018, 1149	W	Aromatic C-H	
799	W	Subst. Olefin/ Aromatic	
755	S	Subst. Aromatic	

TABLE A-57. IR REPORT--SAMPLE NO. B2SWD, CUT LC-6 & 7

- Quantity Not Sufficient -

TABLE A-58. IR REPORT--SAMPLE NO. B-PE, CUT LC-1 & 2

- Quantity Not Sufficient -

TABLE A-59. IR REPORT--SAMPLE NO. B-PE, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2933, 2966	S	Sat'd C-H	
2862	M	Sat'd C-H	
1739	S	Ketone	Poss. Contamination
1460	M	Sat'd C-H	
1378	W	Sat'd C-H	
1082, 1136, 1290	M	Ether, Ketone	
961	W	Alkyl	
748	W	Alkyl, C-Cl	

TABLE A-60. IR REPORT--SAMPLE NO. B-PE, CUT LC-4

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2933, 2966	S	Sat'd C-H	
2862	M	Sat'd C-H	
1739	S	Ester, Ketone	
1246	W	Silicone, Ester, Ether, Sat'd C-H, Ketone	
1136, 1175	M	Ester, Ether	
1076	W	Ether, Silicone	
753	W	Alkyl	

TABLE A-61. IR REPORT--SAMPLE NO. B-PE, CUT LC-5

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2966	M	Sat'd C-H	
2862, 2933	M	Sat'd C-H	
1734	S	Ester	
1175	M	Ether, Ester	
1021, 1087	W	Ether	
753	W	Alkyl	

TABLE A-62. IR REPORT--SAMPLE NO. B-PE, CUT LC-6

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2939, 2955	M	Sat'd C-H	
2846	W	Sat'd C-H	
1027	S	Sulfoxide	
758	W	Alkyl	

TABLE A-63. IR REPORT--SAMPLE NO. B-PE, CUT LC-7

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2966	M	Sat'd C-H	
2868	W	Sat'd C-H	
1734	S	Ketone, Ester	
1252	M	Ester, Ketone, Phosphate	
1175	W	Ester	
1016	W	Phosphate	
753	W	Alkyl	

TABLE A-64. IR REPORT--SAMPLE NO. B2K, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2928	S	Sat'd C-H	
2857, 2959	M	Sat'd C-H	

TABLE A-65. IR REPORT--SAMPLE NO. B2K, CUT LC-2, 3, 4, 5, & 6

- Quantity Not Sufficient -

TABLE A-66. IR REPORT--SAMPLE NO. B2K, CUT LC-7

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2936, 2967	S	Sat'd C-H	
2873	M	Sat'd C-H	
1730	S	Ester, Ketone	
1260	S	Ester, Phosphate Silicone	
1127	M	Sat'd C-H	
1027	S	Sulfoxide, Phosphate, Silicone	
806	S	Phosphate, Alkyl	

TABLE A-67. IR REPORT--SAMPLE NO. C1SWD, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3060	M	Unsat'd C-H	
2923	S	Sat'd C-H	
2868	M	Sat'd C-H	
1456	M	Sat'd C-H	
1275	W	Sat'd C-H	
1187	W	Sat'd/Aromatic C-H	
881	W	Subst. Olefin/ Aromatic	
815	M	Subst. Olefin/ Aromatic	
749	S	Subst. Aromatic, C-Cl	

TABLE A-68. IR REPORT--SAMPLE NO. C1SWD, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3060	S	Unsat'd C-H	
2923-2972	M	Sat'd C-H	Broad
1598	W	Aromatic C=C	
1258	W	Sat'd C-H	
1182	W	Sat'd/Aromatic C-H	
886	W	Subst. Olefin/ Aromatic	
842	M	Subst. Olefin/ Aromatic	
815	M	Subst. Olefin/ Aromatic	
749	S	Subst. Aromatic, C-Cl	
711	M	Subst. Aromatic, C-Cl	

TABLE A-69. IR REPORT--SAMPLE NO. C1SWD, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3060	M	Unsat'd C-H	
2939, 2961	M	Sat'd C-H	
2868	W	Sat'd C-H	
1729	M	Ketone, Aldehyde, Ester	Poss. Contamination
1620	W	Aromatic C=C	
1461	M	Sat'd C-H	
1390	W	Aldehyde	
1275	M	Sat'd C-H, Ketone	
1182	W	Sat'd/Aromatic C-H, Ester	
881	M	Subst. Olefin/ Aromatic	
815	M	Subst. Olefin/ Aromatic	
749	S	Subst. Aromatic, C-Cl	

TABLE A-70. IR REPORT--SAMPLE NO. C1SWD, CUT LC-4

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3060	W	Unsat'd C-H	
2934, 2967	S	Sat'd C-H	
2868	M	Sat'd C-H	
1729	S	Ketone, Ester	Poss. Contamination
1598	M	Aromatic C=C	
1461	M	Sat'd C-H	
1379	W	Sat'd C-H	
1138-1275	M	Ketone, Ester, Aromatic	Broad
1029, 1078	W	Ether, Aromatic	
821, 886	W	Subst. Olefin/ Aromatic	
749	S	Subst. Aromatic/ C-Cl	

TABLE A-71. IR REPORT--SAMPLE NO. C1SWD, CUT LC-5

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3043	W	Unsat'd C-H	
2967	M	Sat'd C-H	
2868	W	Sat'd C-H	
1696	W	Ketone	
1598	M	Aromatic C=C	
1456	M	Sat'd C-H	
1160-1275	M	Ketone, Aromatic	Broad
749	S	Subst. Aromatic, C-Cl	

TABLE A-72. IR REPORT--SAMPLE NO. C1SWD, CUT LC-6

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3060	W	Unsat'd C-H	
2934-2978	M	Sat'd C-H	
1652	S	Amide, Olefin	
1603	M	Aromatic C=C, Olefin	
1456	M	Sat'd C-H	
1373	W	Sat'd C-H	
1275	M	Sat'd C-H	
1034	W	Aromatic C-H	
826	W	Subst. Olefin/ Aromatic	
749	S	Subst. Aromatic, C-Cl	

TABLE A-73. IR REPORT--SAMPLE NO. C1SWD, CUT LC-7

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2972	M	Sat'd C-H	Broad
1653	M	Amide, Olefin	Broad
1598	W	Aromatic C=C, Olefin	Broad
1368	W	Sat'd C-H	
1275	W	Sat'd C-H	
749	S	Subst. Aromatic, C-Cl	

TABLE A-74. IR REPORT--SAMPLE NO. C-P50, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3056	W	Unsat'd C-H	
2955	M	Sat'd C-H	
2931	S	Sat'd C-H	
2859	W	Sat'd C-H	
1457	M	Sat'd C-H	
1379	W	Sat'd C-H	
1115, 1187	W	Sat'd/Aromatic C-H	
828, 876	W	Subst. Olefin/ Aromatic	
750		Subst. Aromatic, C-Cl	

TABLE A-75. IR REPORT--SAMPLE NO. C-P50, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3050	M	Unsat'd C-H	
2925	W	Sat'd C-H	
1601	W	Aromatic C=C	
1451	M	Sat'd C-H	
1379	W	Sat'd C-H	
1301	W	Olefinic C-H	
1265	W	Sat'd C-H	
1181	W	Aromatic, Sat'd C-H	
1037	W	Aromatic C-H	
953	W	Subst. Olefin/ Aromatic	
881	M	Subst. Olefin/ Aromatic	
816, 840	S	Subst. Olefin/ Aromatic	
738	S	Subst. Aromatic, C-Cl	
714	M	Subst. Aromatic, C-Cl	

TABLE A-76. IR REPORT--SAMPLE NO. C-P50, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3050	S	Unsat'd C-H	
2925	M	Sat'd C-H	
2859, 2967	W	Sat'd C-H	
1457	S	Sat'd C-H	
1385	W	Sat'd C-H	
1181	M	Sat'd C-H	
1031	W	Aromatic C-H	
947	W	Subst. Olefin/ Aromatic	
881	M	Subst. Olefin/ Aromatic	
840	M	Subst. Olefin/ Aromatic	Doublet
750	S	Subst. Aromatic, C-Cl	
620	W	C-Cl	

TABLE A-77. IR REPORT--SAMPLE NO. C-P50, CUT LC-4

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3422	M	O-H, N-H	Broad
3056	M	Unsat'd C-H	
2931	M	Sat'd C-H	
2871, 2967	W	Sat'd C-H	
1702	M	Ketone, Aldehyde	
1601	M	Amine, Aromatic C=C	
1451	S	Alcohol, Sat'd C-H	
1277, 1324, 1378	W	Aldehyde, Ketone	
1199, 1241	W	Aldehyde, Ketone	
882	W	Subst. Olefin/ Aromatic	
816	M	Subst. Olefin/ Aromatic, Amine	
750	S	Subst. Aromatic, Alcohol, Amine	

TABLE A-78. IR REPORT--SAMPLE NO. C-P50, CUT LC-5

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3398	M	N-H, O-H	Broad
3056	W	Unsat'd C-H	
2871, 2961	W	Sat'd C-H	
2937	S	Sat'd C-H	
1738	S	Ketone, Ester	
1600	S	Aromatic C=C, Amine	
1457	S	Sat'd C-H, Alcohol	
1379	W	Sat'd C-H, O-H	
1241	S	Ketone, Ester, Ether	
965	W	Subst. Olefin/ Aromatic	
840	M	Subst. Olefin/ Aromatic, Amine	
750	M	Subst. Aromatic, Alcohol	
612, 702	W	Alcohol	

TABLE A-79. IR REPORT--SAMPLE NO. C-P50, CUT LC-6

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3308	S	N-H, O-H	
3068	W	Unsat'd C-H	
2937	M	Sat'd C-H	
2859, 2967	W	Sat'd C-H	
1708	S	Acid, Ketone	
1601	S	Aromatic C=C, Amine	
1457	S	Sat'd C-H, Alcohol	
1271	S	Amine, Acid	Multiplet
1079	W	Amine, Alcohol, Aromatic C-H	
828	M	Olefinic/Aromatic C-H	
756	S	Subst. Aromatic, Alcohol, Amine	
696	M	Alcohol, Alkyl	

TABLE A-80. IR REPORT--SAMPLE NO. C-P50, CUT LC-7

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3400	S	N-H, O-H	Broad
2847	W	Sat'd C-H	
1654	S	Amide	
1451	W	Sat'd C-H	
1409	W	Amide, Alcohol	
1115	W	Amine, Alcohol	
1019	S	Alcohol	
690	S	Alcohol, Alkyl	

TABLE A-81. IR REPORT--SAMPLE NO. C1PART, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2928	S	Sat'd C-H	
2857	M	Sat'd C-H	

TABLE A-82. IR REPORT--SAMPLE NO. C1PART, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3053	S	Unsat'd C-H	
2865, 2967	M	Sat'd C-H	
2928	S	Sat'd C-H	
1456	S	Sat'd C-H	
884	W	Subst. Aromatic, Olefin	
814	M	Subst. Aromatic	
744	S	Subst. Aromatic, Alkyl, C-Cl	

TABLE A-83. IR REPORT--SAMPLE NO. C1PART, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3053	S	Unsat'd C-H	
2920	M	Sat'd C-H	
2857	W	Sat'd C-H	
1597	M	Aromatic C=C	
1456	S	Sat'd C-H	
1198	M	Aromatic C-H	Broad
884	S	Subst. Aromatic	Multiplet
751	S	Subst. Aromatic Alkyl, C-Cl	

TABLE A-84. IR REPORT--SAMPLE NO. C1PART, CUT LC-4

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3053	M	Unsat'd C-H	
2850, 2912	W	Sat'd C-H	
1180	S	Ether, Aromatic, Alkyl	
814, 877	M	Subst. Aromatic	
744	S	Subst. Aromatic, Alkyl	

TABLE A-85. IR REPORT--SAMPLE NO. C1PART, CUT LC-5

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3421	W	O-H, N-H	
3053	W	Unsat'd C-H	
2865, 2959	M	Sat'd C-H	
2928	S	Sat'd C-H	
1738	S	Ketone, Ester	
1604	W	Aromatic C=C, Amine	
1378, 1456	M	Sat'd C-H	
1150 - 1300	S	Ketone, Ester, Alcohol, Phenol	Broad
1080	M	Aromatic C-H	
845, 963	W	Subst. Aromatic	
751	M	Subst. Aromatic, Amine, Alkyl	

TABLE A-86. IR REPORT--SAMPLE NO. C1PART, CUT LC-6

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2936	M	Sat'd C-H	
2865	M	Sat'd C-H	
1738	S	Ester, Ketone	
1605, 1651	W	Amide, Olefin	
1378, 1456	M	Sat'd C-H	
1150 - 1300	M	Ketone, Ester	Broad
1080	W	Sat'd C-H	
751	W	Alkyl	

TABLE A-87. IR REPORT--SAMPLE NO. C1PART, CUT LC-7

- Quantity Not Sufficient -

TABLE A-88. IR REPORT--SAMPLE NO. C1X, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3053	S	Unsat'd C-H	
2740, 2857, 2928	S	Sat'd C-H	
1934	W	Aromatic Overtone	
1597	M	Aromatic C=C	
1511	M	Aromatic C=C	
1476	M	Sat'd C-H	
1425	M	Sat'd/Olefin C-H	
1386	M	Sat'd C-H	
1010, 1080, 1127, 1268	W	Aromatic C-H	
830	M	Subst. Aromatic	
783	M	Subst. Aromatic, Alkyl, C-Cl	
728	M	Subst. Aromatic, Alkyl, Olefin, C-Cl	

TABLE A-89. IR REPORT--SAMPLE NO. C1X, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3061	S	Unsat'd C-H	
2967, 2865	W	Sat'd C-H	
2928	M	Sat'd C-H	
1808, 1934	W	Aromatic Overtone	
1730	M	Ester	Poss. Contamination
1604	M	Aromatic C-H	
1425, 1456	S	Sat'd/Olefin C-H, Silicone	
1080, 1190	M	Silicone, Ester	
830	S	Subst. Aromatic	
775	S	Subst. Aromatic, Alkyl, C-Cl	
736	S	Subst. Aromatic, Alkyl, Olefin, C-Cl	

TABLE A-90. IR REPORT--SAMPLE NO. C1X, CUT LC-3

- Quantity Not Sufficient -

TABLE A-91. IR REPORT--SAMPLE NO. C1X, CUT LC-4

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2866, 2959	W	Sat'd C-H	
2936	M	Sat'd C-H	
1739	S	Ester, Ketone	Poss. Contamination
1457, 1379	W	Sat'd C-H	
1136 - 1285	M	Ester, Ether, Ketone	
1081	W	Silicone	

TABLE A-92. IR REPORT--SAMPLE NO. C1X, CUT LC-5, 7

- Quantity Not Sufficient -

TABLE A-93. IR REPORT--SAMPLE NO. C1X, CUT LC-6

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3312	S	O-H, N-H	Broad
3061	W	Unsat'd C-H	
2936	S	Sat'd C-H	
2866	M	Sat'd C-H	
1707	S	Acid, Amide	
1606	M	Amine, Amide	
1378, 1449	M	Sat'd C-H	
1000 - 1300	M	Alcohol, Phenol, Amine	Broad
760	M	Subst. Aromatic, Alkyl, Alcohol, Amine	

TABLE A-94. IR REPORT--SAMPLE NO. C2SWD, CUT LC-1

- Quantity Not Sufficient -

TABLE A-95. IR REPORT--SAMPLE NO. C2SWD, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3058	W	Unsat'd C-H	
2968	W	Sat'd C-H	
1451	W	Sat'd C-H	
1260	S	Sat'd C-H, Ether	Poss. Contamination
1186	W	Sat'd/Aromatic C-H	
1096	S	Aromatic C-H, Ether	
1027	M	Ether, Aromatic C-H	
800	S	Olefin/Aromatic C-H	
742	M	Subst. Aromatic, C-Cl	

TABLE A-96. IR REPORT--SAMPLE NO. C2SWD, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3052	S	Unsat'd C-H	
2931, 2962	M	Sat'd C-H	
2862	W	Sat'd C-H	
1736	S	Ketone, Ester	Poss. Contamination
1599	M	Aromatic C-H	
1451	S	Sat'd C-H, Aromatic C-H	
1381	W	Sat'd C-H	
1038 - 1287	M	Ester, Ketone	Multiplet
742 - 843	S	Subst. Aromatic, C-Cl	Multiplet
615	M	C-Cl	

TABLE A-97. IR REPORT--SAMPLE NO. C2SWD, CUT LC-4

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3056	W	Unsat'd C-H	Broad
1451	W	Sat'd C-H	
1325	W	Sat'd C-H	
1241	W	Sat'd C-H, Ether	
882	W	Subst. Olefin/ Aromatic	
840	M	Subst. Olefin/ Aromatic	
750	S	Subst. Aromatic	

TABLE A-98. IR REPORT--SAMPLE NO. C2SWD, CUT LC-5

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3404	M	N-H, O-H	Broad
3056	M	Unsat'd C-H	
2931	W	Sat'd C-H	
2865	M	Sat'd C-H	
2224	W	Nitrite	
1738	S	Ketone, Ester	
1600	S	Olefin, Aromatic C=C, Amine	
1451	S	Alcohol, Sat'd C-H, Aromatic C=C	
1379	W	Sat'd C-H	
1175, 1282	S	Ester, Alcohol, Ketone, Amine	
953	W	Olefinic/Aromatic C-H	
840, 882	M	Olefinic/Aromatic C-H	
756	S	Subst. Aromatic	

TABLE A-99. IR REPORT--SAMPLE NO. C2SWD, CUT LC-6

- Quantity Not Sufficient -

TABLE A-100. IR REPORT--SAMPLE NO. C-PE, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2928	S	Sat'd C-H	
2857	M	Sat'd C-H	
748	M	Alkyl, C-Cl	

TABLE A-101. IR REPORT--SAMPLE NO. C-PE, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2928, 2966	S	Sat'd C-H	
2868	M	Sat'd C-H	
1734	S	Ketone, Ester	Poss. Contamination
1284	M	Sat'd C-H, Ketone	
1191	M	Sat'd C-H, Ester	
961	W	Alcohol	
748	M	Alkyl, C-Cl	

TABLE A-102. IR REPORT--SAMPLE NO. C-PE, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2831, 2961	S	Sat'd C-H	
2862	M	Sat'd C-H	
1745	S	Ketone, Ester	Poss. Contamination
1460	M	Sat'd C-H	
1383	W	Sat'd C-H	
1279	S	Sat'd C-H, Ketone	
1082, 1175	S	Ester, Sat'd C-H	
967	M	Alkyl	
753	W	Alkyl, C-Cl	

TABLE A-103. IR REPORT--SAMPLE NO. C-PE, CUT LC-4

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2933, 2966	S	Sat'd C-H	
2868	M	Sat'd C-H	
1262	W	Sat'd C-H	
1175	W	Sat'd C-H	
748	M	Alkyl	

TABLE A-104. IR REPORT--SAMPLE NO. C-PE, CUT LC-5

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2939, 2966	S	Sat'd C-H	
2862	M	Sat'd C-H	
1262	W	Sat'd C-H	
764	S	Alkyl	
748	S	Alkyl	

TABLE A-105. IR REPORT--SAMPLE NO. C-PE, CUT LC-6

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2950	S	Sat'd C-H	
2862	M	Sat'd C-H	
1021	W	Sulfoxide	
764	S	Alkyl	

TABLE A-106. IR REPORT--SAMPLE NO. C-PE, CUT LC-7

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2933, 2966	M	Sat'd C-H	
2862	W	Sat'd C-H	
1740	S	Ketone, Ester	
1264	M	Ketone	
1138, 1176	M	Ester	
1083	W	Alkyl	
957	W	Alkyl	
749	W	Alkyl	

TABLE A-107. IR REPORT--SAMPLE NO. C2PART, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3053	W	Unsat'd C-H	
2928	S	Sat'd C-H	
2857	M	Sat'd C-H	
1456	M	Sat'd C-H	
845	M	Subst. Aromatic	Doublet
736	S	Alkyl, Subst. Aromatic, C-Cl	

TABLE A-108. IR REPORT--SAMPLE NO. C2PART, CUT LC-2

- Quantity Not Sufficient -

TABLE A-109. IR REPORT--SAMPLE NO. C2PART, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3053	S	Unsat'd C-H	
2857, 2928	W	Sat'd C-H	
1918	W	Aromatic Overtone	
1598	M	Aromatic C-H	
1441	M	Sat'd/Olefinic C-H	
1183	M	Aromatic/Sat'd C-H	Multiplet
878	M	Subst. Aromatic	
839	M	Subst. Aromatic	
753	S	Subst. Aromatic, Alkyl, C-Cl	

TABLE A-110. IR REPORT--SAMPLE NO. C2PART, CUT LC-4, 5, 6, & 7

- Quantity Not Sufficient -

TABLE A-111. IR REPORT--SAMPLE NO. C2X, CUT LC-1

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3061	M	Unsat'd C-H	
962, 1010, 1080, 1127	M	Aromatic C-H	
728, 775, 830	S	Subst. Aromatic, C-Cl	

TABLE A-112. IR REPORT--SAMPLE NO. C2X, CUT LC-2

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3045	M	Unsat'd C-H	
775, 814	M	Subst. Aromatic	
736	S	Subst. Aromatic, C-Cl	

TABLE A-113. IR REPORT--SAMPLE NO. C2X, CUT LC-3

Wave Number (cm^{-1})	Intensity	Assignment	Comment
3053	W	Unsat'd C-H	
2936, 2959	S	Sat'd C-H	
2857	M	Sat'd C-H	
1738	S	Ester, Ketone	Poss. Contamination
1464	M	Sat'd C-H	
1378	M	Sat'd C-H	
1135-1292	M	Ketone, Silicone, Ester, Sat'd/ Aromatic C-H	Multiplet
1080	M	Aromatic C-H, Silicone	
822, 963	W	Subst. Aromatic	
744	M	Subst. Aromatic, Alkyl, C-Cl	

TABLE A-114. IR REPORT--SAMPLE NO. C2X, CUT LC-4

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2936, 2967	M	Sat'd C-H	
2865	M	Sat'd C-H	
1738	S	Ketone, Ester	
1456	W	Sat'd C-H	
1378	W	Sat'd C-H	
1135-1252	M	Ether, Ester, Ketone, Silicone	Multiplet
1080	M	Ether, Silicone	
735	W	Alkyl, C-Cl	

TABLE A-115. IR REPORT--SAMPLE NO. C2X, CUT LC-5

- Quantity Not Sufficient -

TABLE A-116. IR REPORT--SAMPLE NO. C2X, CUT LC-6

Wave Number (cm^{-1})	Intensity	Assignment	Comment
2936	M	Sat'd C-H	
2865	W	Sat'd C-H	
1738	S	Ketone, Ester	
1456	W	Sat'd C-H	
1378	W	Sat'd C-H	
1174-1244	M	Ketone, Ester	Multiplet

TABLE A-117. IR REPORT--SAMPLE NO. C2X, CUT LC-7

- Quantity Not Sufficient -

APPENDIX B

LOW RESOLUTION MASS SPECTROGRAPH REPORTS

TABLE B-1. LRMS REPORT--SAMPLE NO. A1X, LC CUT 2 & 3 COMBINED

Intensity	Category	MW Range	m/e	Composition
Major Categories				
100	Aliphatics	149-283		
Sub-Categories, Specific Compounds				
10	Probably Fragment		149	$C_{11}H_{17}$
10	Probably Fragment		183	$C_{13}H_{27}$
10	Aliphatic with Two Sites of Unsaturation		236	$C_{17}H_{32}$
100	Probably Fragment		255	$C_{18}H_{39}$
100	Probably Fragment		283	$C_{20}H_{43}$

Other

IR shows no evidence of aromatic structures.

TABLE B-2. LRMS REPORT--SAMPLE NO. A1-SWD, LC CUT 2

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	202		
100	Fused Aromatics, MW >216	252-314		
Sub-Categories, Specific Compounds				
100	Phthalate Fragment		149	$C_8H_5O_3$
10	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Probably Fragment		213	
100	Probably Fragment		243	
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
10	Dimethylbenzanthracene		256	$C_{20}H_{16}$
10			258	$C_{20}H_{18}$
100	Probably Fragment		279	
10	Probably Fragment		299	
10	Methyl Coronene		314	$C_{25}H_{14}$
Other				
Quantity not sufficient for IR.				

TABLE B-3. LRMS REPORT--SAMPLE NO. A1-SWD, LC CUT 3

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	202		
100	Fused Aromatics, MW >216	228-302		
10	Ester/Ketone	-		
Sub-Categories, Specific Compounds				
100	Phthalate Fragment		149	$C_8H_5O_3$
100	Probably Fragment		167	
10	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Probably Fragment		213	
10	Benzanthracene, Chrysene		228	$C_{18}H_{12}$
100	Probably Fragment		243	
10	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
10	Dimethyl Benzanthracene		256	$C_{20}H_{16}$
10			258	$C_{20}H_{18}$
100	Probably Fragment		279	
10	Probably Fragment		287	
10	Probably Fragment		299	
10	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
10	Methyl Coronene		314	$C_{25}H_{14}$
Other				
Quantity not sufficient for IR.				

TABLE B-4. LRMS REPORT--SAMPLE NO. A2-X, LC CUT 2 & 3

Intensity	Category	MW Range	m/e	Composition
Major Categories				
100	Fused Aromatics, MW >216	276-338		
100	Alkyl Fragments	255-613		
Sub-Categories, Specific Compounds				
100	Probably Fragment		255	$C_{18}H_{39}$
10	Probably Fragment		257	$C_{18}H_{41}$
10	Anthanthrene, Indenopyrene		276	$C_{22}H_{12}$
10	Probably Fragment		283	$C_{20}H_{43}$
10	Coronene		300	$C_{24}H_{12}$
100	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
10	Probably Fragment		311	$C_{24}H_{23}$; $C_{23}H_{35}$
10	Benzanthanthrene		326	$C_{26}H_{14}$
10			338	
10	Probably Fragment		339	
10	Probably Fragment		543	
100	Probably Fragment		557	
100	Probably Fragment		571	
100	Probably Fragment		585	
100	Probably Fragment		599	
10	Probably Fragment		613	

Other

Quantity not sufficient for IR.

TABLE B-5. LRMS REPORT--SAMPLE NO. A2-SWD, LC CUT 2

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatic, MW <216	202		
100	Fused Aromatics, MW >216	228-452		
Sub-Categories, Specific Compounds				
100	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
100	Benzanthracene, Chrysene		228	$C_{18}H_{12}$
100	Methyl Chrysene		242	$C_{19}H_{14}$
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
100	Dibenzofluorene		266	$C_{21}H_{14}$
10	Methyl Cholanthrene		268	$C_{21}H_{16}$
100	Anthanthracene, Indenopyrene		276	$C_{22}H_{12}$
10	Dibenzanthracene		278	$C_{22}H_{14}$
100	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
100	Benzanthanthrene		326	$C_{26}H_{14}$
10	Dinaphthanthracene		378	$C_{30}H_{18}$
10	Dinaphthopyrene		402	$C_{32}H_{18}$
10			428	
10			452	
Other				
IR showed no evidence of other functional groups.				

TABLE B-6. LRMS REPORT--SAMPLE NO. A2-SWD, LC CUT 3

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	202		
100	Fused Aromatics, MW >216	228-452		
10	Esters/Ketones	202-452		
Sub-Categories, Specific Compounds				
10	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Benzanthracene, Chrysene		228	$C_{18}H_{12}$
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
10	Dibenzofluorene		266	$C_{21}H_{14}$
100	Anthanthrene, Indenopyrene		276	$C_{22}H_{12}$
100	Dibenzanthracene		278	$C_{22}H_{14}$
10	Methyl Dibenzanthracene		292	$C_{23}H_{16}$
100	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
100	Benzanthanthrene		326	$C_{26}H_{14}$
10	Dibenzochrysene Isomer		328	$C_{26}H_{16}$
100	Dibenzanthanthrene Isomer		376	$C_{30}H_{16}$
10	Dinaphthanthracene		378	$C_{30}H_{18}$
10	Dinaphthopyrene		402	$C_{32}H_{18}$
10			428	
10			452	

TABLE B-7. LRMS REPORT--SAMPLE NO. A-PE, LC CUT 2

Intensity	Category	MW Range	m/e	Composition
Major Categories				
100	Aliphatics	236-278		
Sub-Categories, Specific Compounds				
100	$C_{17}H_{32}$ Aliphatic Compound		236	$C_{17}H_{32}$
100	Probably Fragment		243	$C_{18}H_{27}$
10	Probably Fragment		255	$C_{18}H_{35}$
10	Probably Fragment		257	$C_{18}H_{37}$
10	$C_{20}H_{34}$ Aliphatic Compound		278	$C_{20}H_{34}$
Other				
Quantity not sufficient for IR.				

TABLE B-8. LRMS REPORT--SAMPLE NO. A-PE, LC CUT 3

Intensity	Category	MW Range	m/e	Composition
Major Categories				
100	Aliphatic	236-604		
10	Ketones (Contaminant)	-		
Sub-Categories, Specific Compounds				
100	Probably Fragment		129	
100	Phthalate Fragment		149	$C_8H_5O_3$
100	$C_{17}H_{32}$ Aliphatic Compound		236	$C_{17}H_{32}$
10	Probably Fragment		239	
10	$C_{19}H_{34}$ Aliphatic Compound		262	$C_{19}H_{34}$
100	$C_{19}H_{36}$ Aliphatic Compound		264	$C_{19}H_{36}$
10	Probably Fragment		279	
10	$C_{23}H_{36}$ Aliphatic Compound		312	$C_{23}H_{36}$
100			369	
100			551	
100			576	
100			577	
100			602	
100			604	

Other

IR showed no aromatic structures.

TABLE B-9. LRMS REPORT--SAMPLE NO. B1-X, LC CUT 2

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	202		
10	Fused Aromatics, MW >216	228		
100	Aliphatics	>554		
Sub-Categories, Specific Compounds				
10	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Benzanthracene, Chrysene		228	$C_{18}H_{12}$

The following major fragment peaks were noted: 553, 503, 479, 429, 420, 417, 405, 369, 355, 343, 327, 295, 281, 221, 207, 147, 135.

TABLE B-10. LRMS REPORT--SAMPLE NO. B1-X, LC CUT 3

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	202		
10	Fused Aromatics, MW >216	228-252		
100	Aliphatics/Aralkyls	>702		
Sub-Categories, Specific Compounds				
10	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Benzanthracene, Chrysene		228	$C_{18}H_{12}$
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$

This spectrum was extremely complex. Major peaks were noted at the following masses: 135, 145, 197, 221, 235, 259, 295, 327, 331, 343, 346, 390, 405, 417, 420, 451, 467, 479.

The most notable pattern was observed in the m/e 529-701 region

701	627	553
692	618	544
677	603	529

Long chain aliphatics or aralkyls.

TABLE B-11. LRMS REPORT--SAMPLE NO. B2-PART, LC CUT 2 & 3 COMBINED

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	202		
100	Fused Aromatics, MW >216	252-426		
Sub-Categories, Specific Compounds				
10	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
10	Dibenzofluorene		266	$C_{21}H_{14}$
100	Anthanthrene, Indenopyrene		276	$C_{22}H_{12}$
10	Methyl Anthanthrene		290	$C_{23}H_{14}$
10			292	$C_{23}H_{16}$
100	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
100	Anthrafluorene		316	$C_{25}H_{16}$
100	Benzanthanthrene		326	$C_{26}H_{14}$
10	Dibenzanthanthrene Isomer		350	$C_{28}H_{14}$
10	Dibenzopentacene		352	$C_{28}H_{16}$
10	Dibenzocoronene Isomer		374	$C_{30}H_{14}$
10	Dibenzanthanthrene Isomer		376	$C_{30}H_{16}$
10	Dibenzocoronene Isomer		400	$C_{32}H_{16}$
10	Dinaphthopyrene		402	$C_{32}H_{18}$
10			426	

TABLE B-12. LRMS REPORT--SAMPLE NO. B2-X, LC CUT 2 & 3 COMBINED

Intensity	Category	MW Range	m/e	Composition
Major Categories				
100	Fused Aromatics, MW <216	152-202		
10	Fused Aromatic, MW >216	216		
Sub-Categories, Specific Compounds				
10	Aralkyl Compound		152	$C_{11}H_{20}$
10	Probably Fragment		165	$C_{12}H_{21}$
100	Phenanthracene, Anthracene		178	$C_{14}H_{10}$
10	Probably Fragment		189	$C_{14}H_{21}$
10	Methyl Anthracene		192	$C_{14}H_{24}$
100	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Benzofluorene, Methyl Pyrene		216	$C_{17}H_{12}$

TABLE B-13. LRMS REPORT--SAMPLE NO. B2-SWD, LC CUT 2

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	202		
100	Fused Aromatics, MW >216	216-328		
100	Aliphatics	290-374		
Sub-Categories, Specific Compounds				
10	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Benzofluorene, Methyl Pyrene		216	$C_{17}H_{12}$
10	Anthanthrene, Indenopyrene		276	$C_{22}H_{12}$
100	Coronene		300	$C_{24}H_{12}$
100	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
100	Dibenzochrysene Isomer		328	$C_{26}H_{16}$

Peaks are present at intervals of 14 mass units within the following ranges:

100	290-374
100	316-372
100	342-370

Aliphatics or Aralkyl Compounds

Other

IR showed no evidence of other functional groups.

TABLE B-14. LRMS REPORT--SAMPLE NO. B2-SWD, LC CUT 3

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	202		
100	Fused Aromatics, MW >216	228-376		
100	Aliphatics	202-430		
10	Ester/Ketone	-		
Sub-Categories, Specific Compounds				
10	Phthalate Ester Fragment		149	$C_8H_5O_3$
10	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Benzanthracene, Chrysene		228	$C_{18}H_{12}$
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
100	Dibenzofluorene		266	$C_{21}H_{14}$
100	Anthanthrene, Indenopyrene		276	$C_{22}H_{12}$
100	Coronene		300	$C_{24}H_{12}$
100	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
100	Anthrafluorene		316	$C_{25}H_{16}$
100	Benzanthanthrene		326	$C_{26}H_{14}$
100	Pyrenofluorene		340	$C_{27}H_{16}$
100	Dibenzanthanthrene Isomer		350	$C_{28}H_{14}$
100	Dibenzanthanthrene Isomer		376	$C_{30}H_{16}$

Peaks are present at intervals of 14 mass units within the following ranges: 280-308; 290-318; 292-320; 302-316; 326-382; 350-406; 352-394; 376-418; 400-428; 402-430. Aliphatic or Aralkyl Compounds.

Other

IR shows presence of carbonyl groups.

TABLE B-15. LRMS REPORT--SAMPLE NO. B-PE, LC CUT 3

Intensity	Category	MW Range	m/e	Composition
Major Categories				
100	Aliphatics	to 390		
10	Ester	-		
Sub-Categories, Specific Compounds				
10	Possible Molecular Ion, Aliphatic		370	
10	Possible Molecular Ion, Aliphatic		390	
The following fragmentations were noted:				
100			112	
100			129	
100			147	
100	Phthalate Peak		149	
10			167	
10			189	
10			212	
100			241	
100			259	
100			279	
Other				
IR showed no aromaticity.				

TABLE B-16. LRMS REPORT--SAMPLE NO. C1-PART, LC CUT 2 & 3

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	178-202		
100	Fused Aromatics, MW >216	252-402		
Sub-Categories, Specific Compounds				
10	Phenanthracene, Anthracene		178	$C_{14}H_{10}$
10	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
10	Dibenzofluorene		266	$C_{21}H_{14}$
100	Anthanthracene, Indenopyrene		276	$C_{22}H_{12}$
10	Methyl Anthanthracene		290	$C_{23}H_{14}$
10	Coronene		300	$C_{24}H_{12}$
10	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
100	Benzanthanthrene		326	$C_{26}H_{14}$
10	Pyrenofluorene		340	$C_{27}H_{16}$
10	Dibenzanthanthrene Isomer		350	$C_{28}H_{14}$
10	Dibenzocoronene Isomer		374	$C_{30}H_{14}$
10	Dibenzanthanthrene Isomer		376	$C_{30}H_{16}$
10	Dibenzocoronene Isomer		400	$C_{32}H_{16}$
10	Dinaphthopyrene		402	$C_{32}H_{18}$

TABLE B-17. LRMS REPORT--SAMPLE NO. C1-X, LC CUT 2 & 3 COMBINED

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	152-202		
100	Fused Aromatics, MW >216	252-376		
10	Esters	152-376		
Sub-Categories, Specific Compounds				
10	Aralkyl Compound		152	$C_{11}H_{20}$
10	Phenanthracene, Anthracene		178	$C_{14}H_{10}$
10	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
100	Anthanthrene, Indenopyrene		276	$C_{22}H_{12}$
10	Coronene		300	$C_{24}H_{12}$
10	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
100	Benzanthanthrene		326	$C_{26}H_{14}$
100	Dibenzanthanthrene Isomer		350	$C_{28}H_{14}$
10	Dibenzanthanthrene Isomer		376	$C_{30}H_{16}$

TABLE B-18. LRMS REPORT--SAMPLE NO. CI-SWD, LC CUT 2

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	178-202		
100	Fused Aromatics, MW >216	216-326		
10	Aliphatics	278-360		
Sub-Categories, Specific Compounds				
10	Phenanthrene, Anthracene		178	$C_{14}H_{10}$
100	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Methyl Pyrene		216	$C_{17}H_{12}$
10	Benzofluoranthene Isomer		226	$C_{18}H_{10}$
10	Benzanthracene, Chrysene		228	$C_{18}H_{12}$
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
100	Dibenzofluorene		266	$C_{21}H_{14}$
100	Anthanthrene, Indenopyrene		276	$C_{22}H_{12}$
10	Methyl Dibenzanthracene		292	$C_{23}H_{16}$
10	Coronene		300	$C_{24}H_{12}$
10	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
100	Benzanthanthrene		326	$C_{26}H_{14}$

Even mass peaks appeared as clusters within the following range: 352-360, 340-346, 326-332, 314-316, 306-310, 290-296, 278-282.

Other

IR showed presence of no other functional group.

TABLE B-19. LRMS REPORT--SAMPLE NO. C1-SWD, LC CUT 3

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	178-202		
100	Fused Aromatics, MW >216	226-352		
10	Ester/Ketone	-		
Sub-Categories, Specific Compounds				
100	Phthalate Peak		149	$C_8H_5O_3$
10	Phenanthrene, Anthracene		178	$C_{14}H_{10}$
10	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
100	Benzofluoranthene Isomer		226	$C_{18}H_{10}$
100	Benzanthracene, Chrysene		228	$C_{18}H_{12}$
10	Methyl Benzofluoranthene		240	$C_{19}H_{12}$
10	Methyl Chrysene		242	$C_{19}H_{14}$
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
100	Dibenzofluorene		266	$C_{21}H_{14}$
100	Anthanthrene, Indenopyrene		276	$C_{22}H_{12}$
10	Methyl Anthanthrene		290	$C_{23}H_{14}$
100	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
10	Methyl Benzocholanthrene		318	$C_{25}H_{18}$
10	Dibenzochrysene Isomer		328	$C_{26}H_{16}$
10	Methyl Dibenzochrysene		342	$C_{27}H_{18}$
10	Dibenzopentacene		352	$C_{28}H_{16}$
10	Dibenzanthanthrene		376	$C_{30}H_{16}$
	Dinaphthanthracene		378	$C_{30}H_{18}$

(Continued)

Table B-19 (continued)

Intensity	Category	MW Range	m/e	Composition

Other

Major fragment peaks were observed at the following masses: 112, 113, 129, 167, 217.

TABLE B-20. LRMS REPORT--SAMPLE NO. C2-PART, LC CUT 2

Intensity	Category	MW Range	m/e	Composition
Major Categories				
100	Fused Aromatics, MW <216	178-202		
10	Fused Aromatics, MW >216	216-228		
Sub-Categories, Specific Compounds				
10	Phenanthracene, Anthracene		178	$C_{14}H_{10}$
100	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Benzofluorene, Methyl Pyrene		216	$C_{17}H_{12}$
10	Benzofluoranthene Isomer		226	$C_{18}H_{10}$
10	Benzanthracene, Chrysene		228	$C_{18}H_{12}$

TABLE B-21. LRMS REPORT--SAMPLE NO. C2-PART, LC CUT 3

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	178-202		
100	Fused Aromatics, MW >216	226-376		
Sub-Categories, Specific Compounds				
10	Phenanthracene, Anthracene		178	$C_{14}H_{10}$
10	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Benzofluoranthene Isomer		226	$C_{18}H_{10}$
10	Benzanthracene, Chrysene		228	$C_{18}H_{12}$
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
100	Anthanthrene, Indenopyrene		276	$C_{22}H_{12}$
100	Coronene		300	$C_{24}H_{12}$
100	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
100	Benzanthanthrene		326	$C_{26}H_{14}$
10	Dibenzanthanthrene Isomer		350	$C_{28}H_{14}$
10	Dibenzopentacene		352	$C_{28}H_{16}$
10	Dibenzocoronene Isomer		374	$C_{30}H_{14}$
10	Dibenzanthanthrene Isomer		376	$C_{30}H_{16}$

Other

IR shows no evidence of other functional groups, only aralkyl structures.

TABLE B-22. LRMS REPORT--SAMPLE NO. C2-X, LC CUT 2 & 3 COMBINED

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	178-202		
100	Fused Aromatics, MW >216	226-350		
10	Esters, Ketones	178-350		
Sub-Categories, Specific Compounds				
100	Phenanthracene, Anthracene		178	$C_{14}H_{10}$
100	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Benzofluoranthene Isomer		226	$C_{18}H_{10}$
10	Benzanthracene, Chrysene		228	$C_{18}H_{12}$
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
10	Dibenzofluorene		266	$C_{21}H_{14}$
100	Anthanthrene, Indenopyrene		276	$C_{22}H_{12}$
10			282	$C_{21}H_{30}$; $C_{22}H_{18}$
10	Coronene		300	$C_{24}H_{12}$
10	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
100	Benzanthanthrene		326	$C_{26}H_{14}$
10	Dibenzanthanthrene Isomer		350	$C_{28}H_{14}$

TABLE B-23. LRMS REPORT--SAMPLE NO. C2-SWD, LC CUT 3

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	178-202		
100	Fused Aromatics, MW >216	216-376		
	Ketones/Esters			
Sub-Categories, Specific Compounds				
10	Phenanthrene, Anthracene		178	$C_{14}H_{10}$
100	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Methyl Pyrene		216	$C_{17}H_{12}$
100	Benzofluoranthene		226	$C_{18}H_{10}$
10	Benzanthracene, Chrysene		228	$C_{18}H_{12}$
10	Methyl Benzofluoranthene		240	$C_{19}H_{12}$
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
10	Dibenzofluorene		266	$C_{21}H_{14}$
100	Anthanthrene, Indenopyrene		276	$C_{22}H_{12}$
100	Coronene		300	$C_{24}H_{12}$
100	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
100	Benzanthanthrene		326	$C_{26}H_{14}$
10	Dibenzanthanthrene Isomer		350	$C_{28}H_{14}$
10	Dibenzopentacene		352	$C_{28}H_{16}$
10	Dibenzanthanthrene Isomer		376	$C_{30}H_{16}$

Other

IR showed evidence of carbonyl function.

TABLE B-24. LRMS REPORT--SAMPLE NO. C-P50, LC CUT 2

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	178-202		
10	Fused Aromatics, MW >216	252-276		
100	Aliphatics	280-350		
Sub-Categories, Specific Compounds				
10	Phenanthrene, Anthracene		178	$C_{14}H_{10}$
100	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
100	Anthanthrene, Indenopyrene		276	$C_{22}H_{12}$
10	Saturated Aliphatic		282	$C_{20}H_{42}$
10	Saturated Aliphatic		296	$C_{21}H_{44}$
100	Saturated Aliphatic		310	$C_{22}H_{46}$
100	Aliphatic, One Site of Unsaturation		280	$C_{20}H_{40}$
100	Aliphatic, One Site of Unsaturation		294	$C_{21}H_{42}$
10	Aliphatic, One Site of Unsaturation		308	$C_{22}H_{44}$
10	Aliphatic, One Site of Unsaturation		322	$C_{23}H_{46}$
10	Aliphatic, One Site of Unsaturation		336	$C_{24}H_{48}$
10	Aliphatic, One Site of Unsaturation		350	$C_{25}H_{50}$
10	Aliphatic, Two Sites of Unsaturation		292	$C_{21}H_{40}$
10	Aliphatic, Two Sites of Unsaturation		306	$C_{22}H_{42}$

(Continued)

Table B-24 (continued)

Intensity	Category	MW Range	m/e	Composition
10	Aliphatic, Two Sites of Unsaturation		320	$C_{23}H_{44}$
10	Aliphatic, Two Sites of Unsaturation		334	$C_{24}H_{46}$
10	Aliphatic, Two Sites of Unsaturation		348	$C_{25}H_{48}$

TABLE B-25. LRMS REPORT--SAMPLE NO. C-P50, LC CUT 3

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	178-202		
100	Fused Aromatics, MW >216	226-376		
Sub-Categories, Specific Compounds				
10	Phenanthrene, Anthracene		178	$C_{14}H_{10}$
10	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Benzofluoranthene Isomer		226	$C_{18}H_{10}$
10	Chrysene		228	$C_{18}H_{12}$
10	Methyl, Benzofluoranthene		240	$C_{19}H_{12}$
10	Methyl Chrysene		242	$C_{19}H_{14}$
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$
100	Dibenzofluorene		266	$C_{21}H_{14}$
100	Anthanthrene, Indenopyrene		276	$C_{22}H_{12}$
10	Methyl Dibenzanthracene		292	$C_{23}H_{16}$
100	Coronene		300	$C_{24}H_{12}$
100	Dibenzochrysene Isomer		302	$C_{24}H_{14}$
10	Anthrafluorene		316	$C_{25}H_{16}$
100	Benzanthanthrene		326	$C_{26}H_{14}$
10	Dibenzanthanthrene Isomer		350	$C_{28}H_{14}$
10	Dibenzanthanthrene Isomer		376	$C_{30}H_{16}$

Other

IR showed evidence of no other functional group.

TABLE B-26. LRMS REPORT--SAMPLE NO. C-TPD, LC CUT 2

Intensity	Category	MW Range	m/e	Composition
Major Categories				
10	Fused Aromatics, MW <216	202		
100	Fused Aromatics, MW >216	216-252		
100	Aliphatics	>279		
100	Ketone/Ester/Ether	>279		
Sub-Categories, Specific Compounds				
10	Phthalate Fragment		149	$C_5H_8O_3$
100	Pyrene, Fluoranthene		202	$C_{16}H_{10}$
10	Methyl Pyrene		216	$C_{17}H_{12}$
100	Benzofluoranthene Isomer		226	$C_{18}H_{10}$
100	Benzanthracene, Chrysene		228	$C_{18}H_{12}$
100	Benzopyrene, Benzofluoranthene		252	$C_{20}H_{12}$

Strong fragment peaks appear at the following masses: 55, 57, 70, 71, 83, 100, 101, 112, 129, 147, 241, 259, 279.

Other

Although IR does not indicate aromaticity, peaks at half mass units in LRMS suggest presence of aromatic compounds.

TABLE B-27. LRMS REPORT--SAMPLE NO. C-TPD, LC CUT 3

Intensity	Category	MW Range	m/e	Composition
Major Categories				
100	Aliphatics	to 602		
100	Ketones/Ester/Ether	to 602		
Sub-Categories, Specific Compounds				
100	Long Chain Ketone/Ester or Other		236	
10	Long Chain Ketone/Ester or Other		264	
10	Long Chain Ketone/Ester or Other		300	
10	Long Chain Ketone/Ester or Other		302	
10	Long Chain Ketone/Ester or Other		350	
100	Long Chain Ketone/Ester or Other		368	
100	Long Chain Ketone/Ester or Other		374	
10-100	Fragment Peaks appear at the following masses: 313, 307, 279, 243, 167, 149, 129, 113, 112			
100	Peaks appear in clusters 14 mass units apart from m/e 466 to 602.			
Other				
	No evidence of aromaticity.			

APPENDIX C

LC ANALYSIS REPORTS

Notice

The reader will notice that some of the data given in this appendix does not match that given in the tables in the main body of the report.

The first block of data in the LC analysis reports gives the Total Sample, Calculated; Total Sample; Amount Taken for LC; and the Amount Recovered after LC. The second line, Total Sample, is the total amount of organic found in the sample extracted and is corrected for amounts withdrawn for TCO, GRAV, and preliminary IRs. It was necessary in some cases to calculate best estimate Total Sample from this data for two reasons. In Tables C-6 and C-8, the entire sample had not been extracted. Therefore, the Total Sample data was multiplied by the ratio of Total Sample Collected to Amount of Sample Extracted to obtain the calculated Total Sample. In Tables C-3, 5, 8, 15, 18, 19, and 20, corrections were made for errors in sample handling. For these samples about 4 liters were filtered for suspended solids determinations. All of this solid was extracted with methylene chloride and a TCO and GRAV determined. Only 2 liters of the filtered water was extracted. The two extracts were combined and fractionated. Obviously the sample fractionated contains a higher proportion of organics from the solids than contained in the original sample. Using the volumes of the samples filtered for solids determination, the volume of filtered water extracted, the TCO and GRAV data for the solids extraction, and the TCO and GRAV data for the combined samples (given in the tables as Total Sample), a value for the TCO and GRAV was calculated that represents the analysis that would have been obtained if the samples had been combined properly. This value is given under Total Sampling, Calculated.

For these samples, the Total Sample, Calculated, value is used wherever the total amount of organic in the sample is given. Although the numbers obtained are not direct analytical data, they should be very close to the true value and are certainly better than the numbers actually obtained by analysis.

The LC fractionation data given on the lower half of the LC analysis report sheets are the actual data obtained in the analysis and are corrected back to the Total Sample (not Total Sample, Calc.) where indicated. Where the difference between Total Sample and Total Sample, Calc. is substantial (Tables C-5, 8, 15, 18, and 19), the LC fraction concentration data was multiplied by the ratio of the two Total Sample concentrations before entering the data into the Organic Summary Tables in the report.

TABLE C- 1. LC ANALYSIS REPORT, SAMPLE NO. A1X

Sample Site Plant A, FCE 1 Sample Acquisition Date 4/4/79

Type of Source FeMn, Undercover Combustion, Scrubber Stack Discharge

Test Number A-1 Sample ID Number A1X

Sample Description XAD-2 Resin, Module Rinse, Condensate

Original Sample Volume or Mass 122.95 gms XAD-2, 1335 mℓ $CH_2C\ell_2$ from Rinses, 126 mℓ H_2O

Analyst Responsible J. Lytle, C. Foust, J. Lodge

Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m^3, ℓ, or kg)[6]
Total Sample, Calc.[1]				
Total Sample[2]	31.8	61.0	92.8	18.26 mg/m^3
Taken for LC[3]	15.9	30.5	46.1	9.07
Recovered[4]	28.2	34.1	62.3	12.3

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m^3, ℓ, or kg)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			4.7	9.4	1.3	0.8	0.5	1.0	10.4	2.0
2			1.4	2.8	1.2	0	1.2	2.4	5.2	1.0
3			1.2	2.4	18.6	0	18.6	37.2	39.6	7.8
4			3.9	7.8	4.0	0	4.0	8.0	15.8	3.1
5			2.0	4.0	2.2	0	2.2	4.4	8.4	1.7
6			0.9	1.8	4.2	0	4.2	8.4	10.2	2.0
7			0	0	3.4	0	3.4	6.8	6.8	1.3
Sum				28.2	34.9		34.1	68.2	96.4	19.0

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C- 2. LC ANALYSIS REPORT, SAMPLE NO. A1SWD

Sample Site Plant A, FCE 1 Sample Acquisition Date 4/4/79
Type of Source FeMn, Undercover Combustion, Scrubber Discharge Water
Test Number A1 Sample ID Number A1SWD
Sample Description Scrubber Discharge Water, Venturi on Primary Emissions
Original Sample Volume or Mass 1962 ML
Analyst Responsible J. Natske, J. Lytle, C. Foust
Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (~~m~~^{3}, L, or ~~kg~~)[6]
Total Sample, Calc.[1]				
Total Sample[2]	0	22.0	22.0	11.2 mg/ℓ
Taken for LC[3]	0*	15.0	15.0	7.6
Recovered[4]	0*	6.0	6.0	3.1

*Conc. TCO was zero before LC.

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (~~m~~^{3}, L, or ~~kg~~)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1				0	1.0	0.8	0.2	0.3	0.3	0.15
2				0	0.2	0	0.2	0.3	0.3	0.15
3				0	1.2	0	1.2	1.8	1.8	0.9
4				0	1.2	0	1.2	1.8	1.8	0.9
5				0	0.6	0	0.6	0.9	0.9	0.45
6				0	1.8	0	1.8	2.6	2.6	1.3
7				0	0.8	0	0.8	1.2	1.2	0.6
Sum				0			6.0	8.9	8.9	4.45

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-3 . LC ANALYSIS REPORT, SAMPLE NO. A-PE

Sample Site Plant A Sample Acquisition Date 4/5/79
Type of Source Ferroalloy, FeMn, SiMn, Electrolytic Cr
Test Number A Sample ID Number A-PE
Sample Description Plant Final Discharge, Aqueous
Original Sample Volume or Mass 2000 ML
Analyst Responsible J. Natske, C. Foust, J. Lytle
Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (~~m~~^{3}, L, or ~~kg~~)[6]
Total Sample, Calc.[1]	0	13.3	13.3	6.65 mg/ℓ
Total Sample[2]	0	16.0	16.0	8.0 mg/ℓ
Taken for LC[3]	0	13.6	13.6	6.8 mg/ℓ
Recovered[4]	0	37.0	37.0	18.5 mg/ℓ

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (~~m~~^{3}, L, or ~~kg~~)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1					0	0.8	0	0	0	0
2					0.4	0	0.4	0.5	0.5	0.25
3					34.6*	0	34.6	40.7	40.7	20.4
4					0.6	0	0.6	0.7	0.7	0.35
5					0	0	0	0	0	0
6					1.0	0	1.0	1.2	1.2	0.6
7					0.4	0	0.4	0.5	0.5	0.25
Sum				0			37.0	43.6	43.6	21.8

*Possible Contamination

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-4 . LC ANALYSIS REPORT, SAMPLE NO. A2-X

Sample Site Plant A Sample Acquisition Date 4/5/79
Type of Source FeMn, Open Furnace, Scrubber Stack Discharge
Test Number A2 Sample ID Number A2-X
Sample Description XAD-2 Resin, Module Rinse
Original Sample Volume or Mass 123.3 gms XAD-2, 865 mℓ Module Rinse
Analyst Responsible J. Lytle, C. Foust
Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m^3, ℓ, or kg)[6]
Total Sample, Calc.[1]				
Total Sample[2]	32.1	151.0	183.1	22.14 mg/m^3
Taken for LC[3]	16.1	75.5	91.6	11.1
Recovered[4]	33.8	49.5	83.3	10.1

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m^3, ℓ, or kg)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			2.7	5.4	2.3	0.8	1.5	3.0	8.4	1.0
2			0.7	1.4	23.0	0	23.0	46.0	47.4	5.7
3			1.5	3.0	2.2	0	2.2	4.4	7.4	0.9
4			4.9	9.8	1.6	0	1.6	3.2	13.0	1.6
5			4.1	8.2	0.6	0	0.6	1.2	9.4	1.1
6			3.0	6.0	14.6	0	14.6	29.2	35.2	4.3
7			0	0	6.0	0	6.6	12.0	12.0	1.5
Sum				33.8			49.5	99.0	132.8	16.1

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C- 5. LC ANALYSIS REPORT, SAMPLE NO. A2-SWD

Sample Site Plant A Sample Acquisition Date 4/5/79

Type of Source FeMn, Open Furnace, Scrubber Water Discharge

Test Number A-2 Sample ID Number A2-SWD

Sample Description Discharge Water from Flooded Disc Venturi

Original Sample Volume or Mass 2000 mℓ Extracted, 7745 mℓ Total for Solids

Analyst Responsible J. Natske, C. Foust, J. Lytle

Calculations and Report Reviewed by R. Handy, W. Westbrook

	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (~~m^3~~, L, or ~~kg~~)[6]
Total Sample, Calc.[1]	0.4	27.8	28.2	14.1 mg/ℓ
Total Sample[2]	1.0	69.0	70.0	35.0
Taken for LC[3]	0.7	44.9	45.6	27.8
Recovered[4]	0.7	43.1	43.8	26.9

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (~~m^3~~, L, or ~~kg~~)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			0.5	0.8	11.3	0.8	10.5	16.1	16.9	8.5
2			0.2	0.3	12.4	0	12.4	19.0	19.3	9.6
3			0	0	9.4	0	9.4	14.4	14.4	7.2
4			0	0	4.0	0	4.0	6.1	6.1	3.1
5			0	0	2.4	0	2.4	3.7	3.7	1.8
6			0	0	2.8	0	2.8	4.3	4.3	2.2
7			0	0	1.6	0	1.6	2.5	2.5	1.3
Sum			0.7	1.1			43.1	66.1	67.2	38.6

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C- 6. LC ANALYSIS REPORT, SAMPLE NO. B1-PW

Sample Site Plant B Sample Acquisition Date 4/25/79

Type of Source 50% FeSi, Open Furnace, Stack before Emission Control

Test Number B-1 Sample ID Number B1-PW

Sample Description SASS System Probe Wash

Original Sample Volume or Mass 3.733 gms - 2.8097 Extracted

Analyst Responsible J. Lytle, C. Foust

Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m^3, ℓ, or Kg)[6]
Total Sample, Calc.[1]		95.7	95.7	7.18 mg/m^3
Total Sample[2]	-	72.0	72.0	5.41
Taken for LC[3]	-	48.0	48.0	3.6
Recovered[4]	-	16.1	16.1	1.2

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m^3, ℓ, or Kg)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1					1.3	0.8	0.5	1.0	1.0	0.1
2					0.4	0	0.4	0.8	0.8	0.06
3					0.4	0	0.4	0.8	0.8	0.06
4					3.0	0	3.0	6.0	6.0	0.45
5					1.6	0	1.6	3.2	3.2	0.24
6					9.8	0	9.8	19.6	19.6	1.47
7					0.4	0	0.4	0.8	0.8	0.06
Sum							16.1	32.2	32.2	2.4

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-7 . LC ANALYSIS REPORT, SAMPLE NO. B1-X

Sample Site Plant B Sample Acquisition Date 4/25/79

Type of Source 50% FeSi, Open Furnace, Stack before Emission Control

Test Number B-1 Sample ID Number B1-X

Sample Description XAD-2 Resin and Module Rinse

Original Sample Volume or Mass 85.32 gms XAD-2, 340 mℓ Module Rinse

Analyst Responsible J. Lytle, C. Foust

Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m^3, ~~ℓ~~, or ~~kg~~)^6
Total Sample, Calc.[1]				
Total Sample[2]	84.0	274.0	358.0	26.87 mg/m^3
Taken for LC[3]	25.2	82.2	170.4	12.8
Recovered[4]	19.9	33.8	53.7	4.0

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m^3, ~~ℓ~~, or ~~kg~~)^6
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			9.4	31.3	3.0	0.8	2.2	7.3	38.6	2.9
2			2.7	9.0	7.4	0	7.4	24.7	33.7	2.5
3			3.0	10.0	13.4	0	13.4	44.7	54.7	4.1
4			1.5	5.0	3.2	0	3.2	10.7	15.7	1.2
5			3.1	10.3	1.8	0	1.8	6.0	16.3	1.2
6			0.2	0.7	3.0	0	3.0	10.0	10.7	0.8
7			0	0	2.8	0	2.8	9.3	9.3	0.7
Sum			19.9	66.3			33.8	112.7	179.0	13.4

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-8 . LC ANALYSIS REPORT, SAMPLE NO. B2-PART

Sample Site Plant B Sample Acquisition Date 5/1/79
Type of Source 50% FeSi, Mix-sealed Furnace, Stack Discharge after Venturi
Test Number B2 Sample ID Number B2-PART
Sample Description Probe Wash and Particle Filters (No Cylcones Used)
Original Sample Volume or Mass 0.4933 gms in Probe Wash, 3.0903 gms on filters
Analyst Responsible 0.4933 gm PW, 2.1823 gms Filter Extracted, J. Lytle, C. Foust
Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m^3, ~~ℓ~~, or ~~kg~~)[6]
Total Sample, Calc.[1]	0	1366	1366	94.85 mg/m^3
Total Sample[2]	0	1020	1020	70.8
Taken for LC[3]	0	51.0	51.0	3.5
Recovered[4]	8.8	27.4	36.2	2.5

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m^3, ~~ℓ~~, or ~~kg~~)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			6.3	126	0	0.8	0	0	126	8.8
2			0.5	10.0	1.4	0	1.4	28	38	2.6
3			1.2	24.0	15.2	0	15.2	304	328	22.8
4			0.8	16.0	5.6	0	5.6	112	128	8.9
5			0	0	1.2	0	1.2	24	24	1.7
6			0	0	3.8	0	3.8	76	76	5.3
7			0	0	0.2	0	0.2	4.0	4	0.3
Sum			8.8	176			27.4	548	724	50.3

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-9 . LC ANALYSIS REPORT, SAMPLE NO. B2-X

Sample Site Plant B Sample Acquisition Date 5/1/79
Type of Source 50% FeSi, Mix-sealed Furnace, Stack Discharge after Venturi
Test Number B-2 Sample ID Number B2-X
Sample Description XAD-2 Resin, Module Rinse, Condensate
Original Sample Volume or Mass 99.29 gms XAD-2, 690 mℓ CH_2Cl_2, 175 mℓ H_2O
Analyst Responsible J. Lytle, C. Foust
Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m^3, ℓ, or kg)[6]
Total Sample, Calc.[1]				
Total Sample[2]	7700	2720	10,420	723.5 mg/m^3
Taken for LC[3]	231	81.6	312.6	21.7
Recovered[4]	412.5	7.4	419.9	29.1.

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m^3, ℓ, or kg)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			302	10,067	0	0.8	0	0	10,067	699.0
2			66.2	2,207	2.6	0	2.6	86.7	2,293.7	159.3
3			35.3	1,177	1.0	0	1.0	33.3	1,210.3	84.0
4			5.5	183.3	0.8	0	0.8	26.7	210	14.6
5			3.3	110	0.6	0	0.6	20.0	130	9.0
6			0.2	6.7	1.8	0	1.8	60.0	66.7	4.6
7			0	0	0.6	0	0.6	20.0	20.0	1.4
Sum			412.5	13,751			7.4	246.7	13,992.7	971.9

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-10. LC ANALYSIS REPORT, SAMPLE NO. B2-K

Sample Site Plant B Sample Acquisition Date 5/1/79

Type of Source 50% FeSi Mix-sealed Furnace

Test Number B-2 Sample ID Number B2-K

Sample Description Kerosene, Injected to Scrubber Blower (Entrained in Stack)

Original Sample Volume or Mass 1 liter, Analysis is for 2 mℓ

Analyst Responsible J. Lodge, J. Lytle, C. Foust

Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m^3, L, or kg)[6]
Total Sample, Calc.[1]				
Total Sample[2], mg/mℓ	663	109.4*	772.4	
Taken for LC[3]	331.5	54.7*	386.2	
Recovered[4]	402.4	0	402.4	

*Suspected Error

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m^3, L, or kg)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			362.5	725.0	0	0.8	0	0	725.0	
2			28.2	56.4	0	0	0	0	56.4	
3			5.7	11.4	0	0	0	0	11.4	
4			4.7	9.4	0	0	0	0	9.4	
5			1.2	2.4	0	0	0	0	2.4	
6			0.1	0.2	0	0	0	0	0.2	
7			0	0	0	0	0	0	0	
Sum			402.4	804.8	0		0	0	804.8	

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-11. LC ANALYSIS REPORT, SAMPLE NO. B2-SWD

Sample Site Plant B Sample Acquisition Date 5/1/79

Type of Source 50% FeSi, Mix-Sealed Furnace, Scrubber Water Discharge

Test Number B2 Sample ID Number B2-SWD

Sample Description Scrubber Water from Primary Emission Control

Original Sample Volume or Mass 2000 mℓ Extracted, 3982 mℓ for Solids

Analyst Responsible J. Natske, J. Lytle, C. Foust

Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (~~m^3~~, L, or ~~kg~~)[6]
Total Sample, Calc.[1]				
Total Sample[2]	183	919	1,102	551.0 mg/ℓ
Taken for LC[3]	18.3	91.9	110.2	55.1
Recovered[4]	14.3	98.7	113.0	56.5

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (~~m^3~~, L, or ~~kg~~)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			5.0	50.0	22.5	0.8	21.7	217	267	133.5
2			1.7	17	25	0	25.0	250	267	133.5
3			0.3	3	24.2	0	24.2	242	245	122.5
4			1.2	12	13.8	0	13.8	138	150	75
5			2.2	22	3.8	0	3.8	38	60	30
6			3.9	39	8.6	0	8.6	86	125	62.5
7			0	0	1.6	0	1.6	16	16	8
Sum			14.3	143			98.7	987	1130	565

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-12. LC ANALYSIS REPORT, SAMPLE NO. B-PE

Sample Site Plant B Sample Acquisition Date 5/1/79

Type of Source Ferroalloy, 50% FeSi, CaC_2

Test Number B Sample ID Number B-PE

Sample Description Plant Final Effluent

Original Sample Volume or Mass 2000 mℓ Extracted, 3983 mℓ for Solids

Analyst Responsible J. Natske, J. Lytle, C. Foust

Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m^3, L, or Kg)^6
Total Sample, Calc.[1]				
Total Sample[2]	3.0	21.0	24.0	12 mg/ℓ
Taken for LC[3]	2.6	17.9	20.5	10.3
Recovered[4]	0.9	10.6	11.5	5.8

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m^3, L, or Kg)^6
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			0.3	0.4	0.8	0.8	0	0	0.4	0.2
2			0	0	0	0	0	0	0	0
3			0	0	3.2	0	3.2	3.8	3.8	1.9
4			0	0	1.8	0	1.8	2.1	2.1	1.05
5			0	0	0.6	0	0.6	0.7	0.7	0.35
6			0.6	0.7	4.4	0	4.4	5.2	5.9	2.95
7			0	0	0.6	0	0.6	0.7	0.7	0.35
Sum			0.9	1.1				12.5	13.6	6.8

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-13. LC ANALYSIS REPORT, SAMPLE NO. C1-PART

Sample Site Plant C Sample Acquisition Date 6/13/79
Type of Source 75% FeSi Mix-sealed Furnace, Stack after Scrubbers
Test Number C-1 Sample ID Number C1-PART
Sample Description Probe Rinse, Filters, and Cyclones
Original Sample Volume or Mass 16.2946 gms Solids
Analyst Responsible J. Lytle, C. Foust
Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m^3, ~~ℓ~~, or ~~kg~~)[6]
Total Sample, Calc.[1]				
Total Sample[2]	13.2	443.0	456.2	23.1 mg/m^3
Taken for LC[3]	2.0	66.5	68.5	3.5
Recovered[4]	0.6	51.0	51.6	2.6

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m^3, ~~ℓ~~, or ~~kg~~)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			0.4	2.7	0.8	0.8	0	0	2.7	0.14
2			0.2	1.3	3.8	0	3.8	25.3	26.6	1.3
3			0	0	17.4	0	17.4	116.0	116.0	5.9
4			0	0	10.4	0	10.4	69.3	69.3	3.5
5			0	0	6.6	0	6.6	44.0	44.0	2.2
6			0	0	11.4	0	11.4	76.0	76.0	3.8
7			0	0	1.4	0	1.4	9.3	9.3	0.5
Sum			0.6	4.0			51.0	339.9	343.9	17.4

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-14. LC ANALYSIS REPORT, SAMPLE NO. C1-X

Sample Site Plant C Sample Acquisition Date 6/13/79

Type of Source 75% FeSi Mix-sealed Furnace, Stack Discharge after Scrubber

Test Number C-1 Sample ID Number C1-X

Sample Description XAD-2 Resin, Module Rinse and Condensate

Original Sample Volume or Mass 83.5 gms XAD-2, 2151 mℓ $CH_2Cℓ_2$, 2499 mℓ H_2O

Analyst Responsible J. Lytle, C. Foust

Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m^3, XX or XXg)[6]
Total Sample, Calc.[1]				
Total Sample[2]	5570	3600	9170	464.3 mg/m^3
Taken for LC[3]	44.6	28.8	73.4	3.7
Recovered[4]	59.2	18.4	77.6	3.9

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m^3, XX, or XX)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			41.5	5,188.0	1.0	0.8	0.2	25.0	5,213.0	264.0
2			9.4	1,175.0	3.4	0	3.4	425.0	1,600.0	81.0
3			0.9	112.5	4.0	0	4.0	500.0	612.5	31.0
4			3.0	375.0	1.8	0	1.8	225.0	600.0	30.4
5			1.4	175.0	1.4	0	1.4	175.0	350.0	17.7
6			3.0	375.0	6.8	0	6.8	850.0	1,225.0	62.0
7			0	0	0.8	0	0.8	100.0	100.0	5.1
Sum			59.2	7,400.5			18.4	2,300.0	9,700.5	491.2

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-15. LC ANALYSIS REPORT, SAMPLE NO. C1-SWD

Sample Site Plant C Sample Acquisition Date 6/13/79

Type of Source 75% FeSi, Mix-sealed Furnace, Scrubber Discharge Water

Test Number C-1 Sample ID Number C1-SWD

Sample Description Water Discharged from Scrubber on Primary Emission

Original Sample Volume or Mass 2000 mℓ Extracted, 3305 mℓ for Solids

Analyst Responsible J. Natske, J. Lytle, C. Foust

Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (~~m^3~~, L, or ~~kg~~)[6]
Total Sample, Calc.[1]	45.0	222.7	267.7	133.9 mg/ℓ
Total Sample[2]	74.3	368.0	442.3	221.1
Taken for LC[3]	18.6	92.0	110.6	55.3
Recovered[4]	11.4	115.1	126.5	63.3

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (~~m^3~~, L, or ~~kg~~)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			3.3	13.7	16.5	0.8	15.7	62.8	76.0	38
2			1.5	6.0	19.8	0	19.8	79.2	85.2	42.6
3			0.9	3.6	38.6	0	38.6	154.4	158.0	79.0
4			1.8	7.2	17.0	0	17.0	68.0	75.2	37.6
5			3.7	14.8	9.2	0	9.2	36.8	51.6	25.8
6			0.2	0.8	12.4	0	12.4	49.6	50.4	25.2
7			0	0	2.4	0	2.4	9.6	9.6	4.8
Sum			11.4	45.6			115.1	460.4	506.0	253.0

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-16. LC ANALYSIS REPORT, SAMPLE NO. C2-PART

Sample Site Plant C Sample Acquisition Date 6/19/79

Type of Source 50% FeSi, Mix-sealed Furnace, Scrubber Discharge Stack

Test Number C-2 Sample ID Number C2-PART

Sample Description Probe Wash, Filters, and Cyclones

Original Sample Volume or Mass 14.8282 gms

Analyst Responsible J. Lytle, C. Foust

Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m^3, ℓ, or kg)[6]
Total Sample, Calc.[1]				
Total Sample[2]	4.7	280.0	284.7	23.8 mg/m^3
Taken for LC[3]	1.4	84.0	85.4	7.2
Recovered[4]	2.2	70.6	72.8	6.1

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m^3, ℓ, or kg)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			1.0	3.3	8.0	0.8	7.2	24.1	27.4	2.3
2			-	-	7.4	0	7.4	24.7	24.7	2.1
3			0	0	28.6	0	28.6	95.3	95.3	8.0
4			0.1	0.3	15.4	0	15.4	51.3	51.3	4.3
5			1.1	3.7	8.0	0	8.0	26.7	30.4	2.5
6			0	0	3.4	0	3.4	11.3	11.3	0.9
7			0	0	0.6	0	0.6	2.0	2.0	0.2
Sum			2.2	7.3				235.4	242.7	20.3

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-17. LC ANALYSIS REPORT, SAMPLE NO. C2-X

Sample Site Plant C Sample Acquisition Date 6/19/79
Type of Source 50% FeSi, Mix-sealed Furnace, Scrubber Discharge Stack
Test Number C-2 Sample ID Number C2-X
Sample Description XAD-2 Resin, Module Rinse, Condensate
Original Sample Volume or Mass 95.69 gms XAD, 1650 mℓ $CH_2C\ell_2$, 1010 mℓ H_2O
Analyst Responsible J. Lytle, C. Foust
Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m^3, ~~ℓ~~, or ~~kg~~)[6]
Total Sample, Calc.[1]				
Total Sample[2]	552.0	1500	2052	171.8 mg/m^3
Taken for LC[3]	13.2	36.0	49.2	4.1
Recovered[4]	119.4	11.6	131.0	11.0

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m^3, ~~ℓ~~, or ~~kg~~)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			81.6	3,400.0	2.8	0.8	2.0	83.3	3,483.3	291.6
2			10.4	433.3	5.0	0	5.0	208.3	641.6	53.7
3			0.7	29.2	1.6	0	1.6	66.7	95.9	8.0
4			0.3	12.5	0.8	0	0.8	33.3	45.8	3.8
5			0	0	0.4	0	0.4	16.7	16.7	1.4
6			0.1	4.2	1.2	0	1.2	50.0	54.2	4.5
7			0	0	0.6	0	0.6	25.0	25.0	2.1
Sum			119.4	3,879.2			11.6	483.3	4,362.5	365.3

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-18. LC ANALYSIS REPORT, SAMPLE NO. C2-SWD

Sample Site Plant C Sample Acquisition Date 6/19/79
Type of Source 50% FeSi Mix-sealed Furnace, Scrubber Discharge Water
Test Number C-2 Sample ID Number C2-SWD
Sample Description Scrubber Water Discharge, Primary Emission Control
Original Sample Volume or Mass 2000 mℓ Water Extracted, 3900 mℓ for Solids
Analyst Responsible J. Natske, J. Lytle, C. Foust
Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (~~m^3~~, L, or ~~kg~~)[6]
Total Sample, Calc.[1]	8.5	133.8	142.3	71.1 mg/ℓ
Total Sample[2]	16.6	261.0	277.6	138.8
Taken for LC[3]	5.0	78.3	83.3	41.7
Recovered[4]	5.7	80.4	86.1	43.1

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (~~m^3~~, L, or ~~kg~~)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			0.4	1.3	2.0	0.8	1.2	4.0	5.3	2.65
2			1.0	3.3	1.0	0	1.0	3.3	6.6	3.3
3			3.6	12.0	54.4	0	54.4	181.3	193.3	96.65
4			0	0	13.8	0	13.8	46.0	46.0	23.0
5			0.7	2.3	4.8	0	4.8	16.0	18.3	9.15
6			0	0	1.8	0	1.8	6.0	6.0	3.0
7			0	0	3.4	0	3.4	11.3	11.3	5.65
Sum			5.7	18.9				267.9	286.8	143.4

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-19. LC ANALYSIS REPORT, SAMPLE NO. C-P50

Sample Site Plant C Sample Acquisition Date 6/19/79
Type of Source 50-75% FeSi, Mix-sealed Furnaces, Wastewater
Test Number C Sample ID Number C-P50
Sample Description Partially Chlorinated Scrubber Discharge Waters
Original Sample Volume or Mass 2000 mℓ Water Extracted, 3873 mℓ for Solids
Analyst Responsible J. Natske, J. Lytle, C. Foust
Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (~~m^3~~, L, or ~~kg~~)[6]
Total Sample, Calc.[1]	22.6	139.4	162.0	81 mg/ℓ
Total Sample[2]	43.8	270.0	313.8	156.9
Taken for LC[3]	13.1	81.0	94.1	47.1
Recovered[4]	11.6	90.2	101.8	50.9

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (~~m^3~~, L, or ~~kg~~)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			1.3	4.3	7.0	0.8	6.2	20.5	25.0	12.5
2			3.4	11.3	9.4	0	9.4	31.3	42.6	21.3
3			1.2	4.0	41.8	0	41.8	139.3	143.3	71.65
4			0.9	3.0	10.4	0	10.4	34.7	37.7	18.85
5			1.8	6.0	7.2	0	7.2	24.0	30.0	15
6			3.0	10.0	14.2	0	14.2	47.3	57.3	28.65
7			0	0	1.0	0	1.0	3.3	3.3	1.65
Sum			11.6	38.6			90.2	300.6	339.2	169.6

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE C-20. LC ANALYSIS REPORT, SAMPLE NO. C-TPD

Sample Site Plant C Sample Acquisition Date 6/19/79
Type of Source 50-75% FeSi, Mix-sealed Furnaces
Test Number C Sample ID Number C-TPD
Sample Description Treated (Chlorination + Settling) Process Discharge Water
Original Sample Volume or Mass 2000 mℓ Water Extracted, 3705 mℓ for Solids
Analyst Responsible J. Natske, J. Lytle, C. Foust
Calculations and Report Reviewed by R. Handy, W. Westbrook

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	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (~~m~~^{3}, L, or ~~kg~~)[6]
Total Sample, Calc.[1]	4.5	11.5	16.0	8.0 mg/ℓ
Total Sample[2]	5.5	14.0	19.5	9.75
Taken for LC[3]	4.7	11.9	16.6	8.3
Recovered[4]	2.8	11.8	14.6	7.3

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (~~m~~^{3}, L, or ~~kg~~)[6]
	Found in Fraction	Blank	Corrected	Total[5]	Found in Fraction	Blank	Corrected	Total[5]		
1			0.3	0.4	0.5	0.8	0	0	0.4	0.2
2			0	0	0.4	0	0.4	0.5	0.5	0.25
3			1.4	1.6	1.4	0	1.4	1.6	3.2	1.6
4			0	0	1.8	0	1.8	2.1	2.1	1.05
5			0.6	0.7	0.6	0	0.6	0.7	1.4	0.7
6			0.5	0.6	6.8	0	6.8	8.0	8.6	4.3
7			0	0	0.8	0	0.8	0.9	0.9	0.45
Sum			2.8	3.3			11.8	13.8	17.1	8.55

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

APPENDIX D

SPARK SOURCE MASS SPECTROGRAPH ORIGINAL DATA

COMMERCIAL TESTING & ENGINEERING CO.
GENERAL OFFICES: 228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601 · AREA CODE 312 726-8434
Reply to INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303-278-9521

To: Mr. Kenneth H. Davis, Jr.
Chemistry and Life Sciences Div.
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC 27709

Date: October 4, 1979

Analyst: J. Oldham

P. O. No.: FURNACE B-1 SASS PROBE SOLIDS

Sample No.: #1

IAD No.: 97-0198-087-04

CONCENTRATION IN PPM WEIGHT

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium	≤0.6	Terbium	0.3	Ruthenium		Vanadium	22
Thorium	8	Gadolinium	≤2	Molybdenum	36	Titanium	860
Bismuth	45	Europium	0.4	Niobium	0.9	Scandium	0.2
Lead	MC	Samarium	4	Zirconium	8	Calcium	MC
Thallium	14	Neodymium	8	Yttrium	2	Potassium	>900
Mercury	NR	Praseodymium	4	Strontium	520	Chlorine	MC
Gold		Cerium	430	Rubidium	140	Sulfur	>450
Platinum		Lanthanum	61	Bromine	84	Phosphorus	MC
Iridium		Barium	350	Selenium	36	Silicon	MC
Osmium		Cesium	3	Arsenic	340	Aluminum	>73
Rhenium		Iodine	7	Germanium	66	Magnesium	MC
Tungsten	4	Tellurium	14	Gallium	240	Sodium	>190
Tantalum	≤0.6	Antimony	23	Zinc	MC	Fluorine	MC
Hafnium		Tin	660	Copper	MC	Oxygen	NR
Lutecium		Indium	STD	Nickel	MC	Nitrogen	NR
Ytterbium		Cadmium	210	Cobalt	6	Carbon	NR
Thulium		Silver	76	Iron	MC	Boron	15
Erbium	0.3	Palladium		Manganese	>74	Beryllium	0.3
Holmium	0.4	Rhodium		Chromium	MC	Lithium	23
Dysprosium	0.6					Hydrogen	NR

STD — Internal Standard
NR — Not Reported
All elements not detected < 0.1 ppm
MC — Major Component
INT — Interference

Approved: M Jacobs

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601 · AREA CODE 312 726-8434

Reply to INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303 278-9521

To: Mr. Kenneth H. Davis, Jr.
Chemistry and Life Sciences Div.
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC 27709

Date: October 4, 1979

Analyst: J. Oldham

P. O. No.: Furnace A-1
SASS Cyclone Particulate, > 3 micron

Sample No.: #2

IAD No.: 97-0198-087-04

CONCENTRATION IN PPM WEIGHT

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium	1	Terbium	≤0.6	Ruthenium		Vanadium	24
Thorium	8	Gadolinium	≤2	Molybdenum	81	Titanium	340
Bismuth	25	Europium	0.9	Niobium	4	Scandium	1
Lead	MC	Samarium	4	Zirconium	19	Calcium	MC
Thallium	3	Neodymium	*8	Yttrium	6	Potassium	>890
Mercury	NR	Praseodymium	17	Strontium	MC	Chlorine	540
Gold		Cerium	*MC	Rubidium	28	Sulfur	>450
Platinum		Lanthanum	76	Bromine	50	Phosphorus	MC
Iridium		Barium	MC	Selenium	22	Silicon	MC
Osmium		Cesium	2	Arsenic	120	Aluminum	>72
Rhenium		Iodine	15	Germanium	16	Magnesium	MC
Tungsten	3	Tellurium	12	Gallium	*240	Sodium	>180
Tantalum		Antimony	140	Zinc	MC	Fluorine	<640
Hafnium	0.9	Tin	290	Copper	MC	Oxygen	NR
Lutecium	<0.1	Indium	STD	Nickel	670	Nitrogen	NR
Ytterbium	0.8	Cadmium	210	Cobalt	1	Carbon	NR
Thulium	0.2	Silver	130	Iron	MC	Boron	5
Erbium	2	Palladium		Manganese	>740	Beryllium	<0.1
Holmium	2	Rhodium		Chromium	MC	Lithium	2
Dysprosium	4					Hydrogen	NR

*Heterogeneous

STD — Internal Standard
NR — Not Reported
All elements not detected < 0.1 ppm
MC — Major Component
INT — Interference

Approved: M Jacobs

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Reply to INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303-278-9521

To: Mr. Kenneth H. Davis, Jr.
Chemistry and Life Sciences Div.
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC 27709

Date: October 4, 1979

Analyst: J. Oldham

P. O. No.: FURNACE B-1
SASS cyclone + Filter PARTICULATE, < 3 micron

Sample No.: #3

IAD No.: 97-D298-087-04

CONCENTRATION IN PPM WEIGHT

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium	≤0.9	Terbium		Ruthenium		Vanadium	4
Thorium	≤1	Gadolinium	0.4	Molybdenum	34	Titanium	MC
Bismuth	76	Europium	0.2	Niobium	0.5	Scandium	≤0.1
Lead	MC	Samarium	0.6	Zirconium	0.8	Calcium	MC
Thallium	3	Neodymium	0.3	Yttrium	0.4	Potassium	MC
Mercury	NR	Praseodymium	0.3	Strontium	490	Chlorine	MC
Gold		Cerium	7	Rubidium	110	Sulfur	>760
Platinum		Lanthanum	3	Bromine	47	Phosphorus	MC
Iridium		Barium	530	Selenium	38	Silicon	MC
Osmium		Cesium	8	Arsenic	MC	Aluminum	>122
Rhenium		Iodine	5	Germanium	220	Magnesium	MC
Tungsten	3	Tellurium	23	Gallium	410	Sodium	>310
Tantalum		Antimony	380	Zinc	MC	Fluorine	≈960
Hafnium		Tin	MC	Copper	MC	Oxygen	NR
Lutecium		Indium	STD	Nickel	13	Nitrogen	NR
Ytterbium		Cadmium	90	Cobalt	<0.1	Carbon	NR
Thulium		Silver	23	Iron	MC	Boron	29
Erbium		Palladium		Manganese	MC	Beryllium	<0.1
Holmium		Rhodium		Chromium	930	Lithium	17
Dysprosium						Hydrogen	NR

STD — Internal Standard
NR — Not Reported
All elements not detected < 0.1 ppm
MC — Major Component
INT — Interference

Approved: M J Jacobs

COMMERCIAL TESTING & ENGINEERING CO.
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Reply to INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303-278-9521

To: Mr. Kenneth A. Davis, Jr.
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, N.C. 27709

FURNACE B-1
SASS FIRST IMPINGER and RINSE

Date: October 17, 1979

Analyst: J. Oldham

P. O. No.: 6925

Sample No.: #4 Liquid

IAD No.: 97-D198-087-04

CONCENTRATION IN μg/ml

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium	≤4	Terbium		Ruthenium		Vanadium	
Thorium	≤5	Gadolinium		Molybdenum		Titanium	MC
Bismuth		Europium		Niobium		Scandium	≤0.7
Lead	46	Samarium		Zirconium		Calcium	MC
Thallium		Neodymium		Yttrium		Potassium	MC
Mercury	NR	Praseodymium		Strontium	5	Chlorine	MC
Gold		Cerium		Rubidium	0.5	Sulfur	MC
Platinum		Lanthanum		Bromine	54	Phosphorus	MC
Iridium		Barium	170	Selenium		Silicon	* MC
Osmium		Cesium		Arsenic		Aluminum	>630
Rhenium		Iodine		Germanium		Magnesium	29
Tungsten		Tellurium		Gallium		Sodium	MC
Tantalum		Antimony		Zinc	MC	Fluorine	
Hafnium		Tin	* 57	Copper	MC	Oxygen	NR
Lutecium		Indium	STD	Nickel	12	Nitrogen	NR
Ytterbium		Cadmium	≤2	Cobalt	≤1	Carbon	NR
Thulium		Silver	26	Iron	* MC	Boron	
Erbium		Palladium		Manganese	* MC	Beryllium	
Holmium		Rhodium		Chromium	0.3	Lithium	4
Dysprosium						Hydrogen	NR

*Heterogeneous D-5

STD — Internal Standard
NR — Not Reported
All elements not detected < 0.5 μg/ml
MC — Major Component
INT — Interference

Approved: ML Jacobs CRW

COMMERCIAL TESTING & ENGINEERING CO.

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Reply to INSTRUMENTAL ANALYSIS DIVISION, 490 ORCHARD STREET, GOLDEN, COLORADO 80401, PHONE: 303-278-9521

To: Mr. Kenneth A. Davis, Jr.
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, N.C. 27709

FURNACE B-1
SASS FIRST IMPINGER and RINSE
(SOLIDS FOUND IN IMPINGER)

Date: October 17, 1979

Analyst: J. Oldham

P. O. No.: 6925

Sample No.: #4 Solid

IAD No.: 97-D198-087-04

CONCENTRATION IN PPM WEIGHT

ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.	ELEMENT	CONC.
Uranium	≤5	Terbium		Ruthenium		Vanadium	
Thorium	≤6	Gadolinium		Molybdenum	≤8	Titanium	8
Bismuth		Europium		Niobium		Scandium	≤0.8
Lead	13	Samarium		Zirconium	4	Calcium	MC
Thallium		Neodymium		Yttrium		Potassium	MC
Mercury	NR	Praseodymium		Strontium	1	Chlorine	290
Gold		Cerium		Rubidium	0.3	Sulfur	MC
Platinum		Lanthanum		Bromine	15	Phosphorus	12
Iridium		Barium	74	Selenium	8	Silicon	MC
Osmium		Cesium		Arsenic		Aluminum	34
Rhenium		Iodine	8	Germanium		Magnesium	≤6
Tungsten		Tellurium		Gallium		Sodium	MC
Tantalum		Antimony		Zinc	45	Fluorine	MC
Hafnium		Tin	160	Copper	2	Oxygen	NR
Lutecium		Indium	STD	Nickel	3	Nitrogen	NR
Ytterbium		Cadmium		Cobalt	≤1	Carbon	NR
Thulium		Silver	72	Iron	41	Boron	3
Erbium		Palladium		Manganese		Beryllium	
Holmium		Rhodium		Chromium	≤2	Lithium	2
Dysprosium						Hydrogen	NR

STD — Internal Standard
NR — Not Reported
All elements not detected < 0.6 ppm
MC — Major Component
INT — Interference

Approved: ML Jacobs crw